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EPHEMERAL EVENTS: ENGLISH BROADSIDES OF EARLY EIGHTEENTH-CENTURY SOLAR ECLIPSES

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Astronomy is an unusually public science; everyone who can see can see the Moon, the stars, the planets, the Milky Way, and unusual objects like comets (especially where there is no street lighting). The point is obvious, but, particularly in the context of better understanding the construction of public science in the eighteenth century, it is also provocative. Constructing a public science — that is, explanations for, and interpretations of, nature and natural phenomena that were at once useful and culturally and socially responsible — occupied many of the most prominent members of the community of scientific practitioners in eighteenth-century England.[1] They shaped the public's understanding of science and its cultural role in large part by means of the market, producing a range of mechanisms for the dissemination of scientific ideas, including books, instruments, lectures, and other formal and informal educational forums.[2] Thus, commerce played a role in mediating the space between the scientific community and the public; people bought a book or paid to see a lecture, and thereby consumed public science.

Astronomy featured prominently in the list of the sciences presented in these forums, and it was eagerly consumed by the public.[3] But astronomy also challenged the ability of the teachers and practitioners to control the public's interpretation and understanding of its phenomena, exactly because of the obvious point mentioned above: astronomy was "public" to an extent unequalled by most other physical sciences associated with the Newtonian enlightenment. The most dramatic phenomena at the heart of the new sciences of mechanics, chemistry, or electricity were largely presented to, and consumed by, the public via lecture demonstrations and commodities such as books and instruments, the prices of which limited their audience. In contrast, an astronomical event was accessible to all, regardless of income or education. For the practitioner or entrepreneur concerned with the construction of public science, astronomy thus offered both a large potential audience for scientific media, and great potential for a public interpretation of its phenomena based in ignorance and superstition.

Unusual astronomical phenomena, such as eclipses and comets, presented special challenges, as their interpretation in the context of public astronomy was complicated by the astrological meanings long associated with them. Astrology enjoyed

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its greatest influence in English culture in the latter half of the seventeenth century, and, while astrology may have lost much of its intellectual legitimacy among the learned of early eighteenth-century England, it still held considerable sway among the populace.[4] The almost visceral fear prompted by dramatic astronomical phenomena like eclipses seemed to blur the distinction between "rational" scientific cause and "irrational" astrological effect. For example, the anonymous author of a woodcut broadside published in advance of the partial solar eclipse of 1699, *The True Figure of that Great Eclipse of the Sun*, criticized the traditional (and obsolete) Ptolemaic scheme of Creation as "Vulgar" and "built upon a very Sandy Foundation", and noted that the eclipse "proceeds only from a Natural cause"; he nevertheless concluded his text with a caution and a prayer: "'Tis observable, That at the Time of this Eclipse, there happens an Opposition of *Saturn* and *Mars*, from *Leo* and *Aquarius*; Perhaps the Astrologers may take Notice of it; I pray God preserve the People of *Good Old England*, and Divert his Judgments from us."[5]

The unique accessibility of astronomical phenomena necessitated a medium for its public interpretation that was also uniquely accessible. That medium was developed early in the century through the modernization of an old European institution: the astrological broadside.[6] Since the development of printing, astrological broadsides had offered single-sheet predictions of doom, often vividly illustrated, based on the appearances of comets, eclipses, meteors, aurorae, and the like. Astronomical broadsides updated the medium by offering scientific explanations of many of the same phenomena, along with appropriate large-scale illustrations. In general, two kinds of prints were published: prints that displayed general facts about the solar system, along with data concerning the orbits of the planets and comets, and prints that contained predictions of forthcoming events, such as planetary transits, or eclipses of the Sun.[7] Their illustrations not only gave them value as "curiosities", they also made them didactically more effective than text-oriented media such as pamphlets and books.[8]

Their intellectual accessibility was matched by a commercial accessibility greater than that of other media; while a basic astronomy text might be had for three shillings, for sixpence or less a curious consumer could acquire an astronomical broadside showing an attractive and interesting illustration with a short explanation. Such a relatively inexpensive item might well have attracted consumers hesitant, or unable, to spend more money on a comprehensive pamphlet or book. Moreover, many of the events illustrated by such ephemera were themselves ephemeral; no medium could be more appropriate for illustrating and explaining to the public a rare and brief event like a solar eclipse than a sixpenny broadside.

Just as astronomical broadsides provided an attractive and accessible medium for astronomical information, so they also provided good possibilities to their producers for personal promotion and the advertisement of related goods. An astronomer who published a broadside of an event inevitably reached an audience beyond the usual readers of the *Philosophical transactions* or the latest book expounding the wonders of Newtonian astronomy; if that astronomer was also a lecturer, teacher,

TABLE 1. Astronomical broadsides published by John Senex.*

Date	Author	Title	Price
1712	William Whiston	*Scheme of the solar system*	2s 6d
1715	William Whiston	*Calculation of the great eclipse of the Sun*	6d
1715	Edmond Halley	*Description of the passage of the shadow of the Moon over England*	6d
1715	William Whiston	*Compleat account of the great eclipse of the Sun*	1s
1715	Edmond Halley	*Description of the passage of the shadow of the Moon over England as it was observed*	6d
1718		*An exact description of the total and visible eclipse of the Moon*	6d
c. 1723		*The Newtonian system of Sun planets and comets*	1s
1723	Edmond Halley	*Description of the passage of the shadow of the Moon over England*	6d
1724	Edmond Halley	*Description of the passage of the shadow of the Moon over Europe*	1s
1736	William Whiston	*The transits of Venus and Mercury over the Sun*	1s
1737	Thomas Wright	*The general construction &c. of a solar eclipse*	1s 6d
1737	Thomas Wright	*The passage of the annular penumbra over Scotland*	1s

*This list is based on “A catalogue of globes, maps, &c. made by the late John Senex, FRS...” (*c*. 1740) which records eleven prints and their prices (Science Museum Library, London, item 1951-685/67). I have examined copies of ten of these broadsides. To this catalogue I have added the first edition of Halley’s *Description of the passage of the shadow of the Moon over England as it was observed*, published just after the eclipse of 1715.

or author, the increased name-recognition could easily translate into expanded markets for his other commercial activities.[9] Similarly, both the writers and the publishers of these broadsides could make use of them to advertise astronomically-themed products — globes, books, telescopes, and the like, as well as other broadsides.

In eighteenth-century London, two businessmen dominated the market for astronomical broadsides. From 1712 until his death in 1740, the bookseller and cartographer John Senex published or sold at least twelve single-sheet prints that addressed astronomical themes, in addition to several star maps, and maps of the Sun and Moon (Table 1).[10] Nine of these focused on eclipses of either the Sun or Moon; one addressed transits of Venus and Mercury; and two presented general information concerning the solar system and its comets. Four were written by William Whiston, four by Edmond Halley, and two by Thomas Wright of Durham. Most included some advertisement for other products available from Senex, especially his globes. Prices of these broadsides ranged from 6 pence to 2 shillings 6 pence.

During the second half of the century, leadership in the astronomical print business shifted to that most energetic marketer of scientific commodities, Benjamin Martin.[11] Between 1739 and around 1765, Martin published nine of his own broadside prints, of which at least eight were astronomically oriented. His first effort, *Synopsis Scientiae Caelestis, or Knowledge of the Heavens and Earth Displayed*, appeared in three editions (in 1739, 1743, and 1752), and sold for three shillings; it was later superseded by his *New Geographical Map; Shewing the First Principles of Geography and Astronomy*, published around 1758, which sold for half the price of the *Synopsis*. The remaining seven astronomical prints all concerned unusual phenomena: three focused on comets; two addressed transits of Venus; and one displayed the paths of totality of the five major solar eclipses of the eighteenth century. These prints sold for between 6 pence and 3 shillings, and provided an opportunity for Martin to advertise other astronomical goods available from his firm (including, for example, his editions of Senex's globes).[12]

In addition to the broadsides published by Senex and Martin, others contributed one or more prints to the market over the course of the century, including Charles Leadbetter, George Smith, George Witchell, Joseph Betts, and Samuel Dunn; a large number of initialled and anonymous prints were also published. In all, over three dozen astronomical broadsides were published during the eighteenth century, most in the fifty years between 1715 and 1765.[13] Of the phenomena addressed in these prints, none appears to have inspired more notice than solar eclipses. The reason has to do with the drama of the phenomenon itself. For example, recording his impressions of the 1715 eclipse for the readers of the *Philosophical transactions*, Edmond Halley commented particularly on "the *Chill* and *Damp* which attended the Darkness of this Eclipse, of which most Spectators were sensible, and equally Judges". Even natural philosophers, he continued, "could not behold it without some sense of Horror".[14]

The British witnessed five major solar eclipses during the first two-thirds of the century, in 1715, 1724, 1737, 1748, and 1764. Each excited greater or lesser degrees of commercial effort and public comment, varying according to how far from London the path of totality ran. Despite the striking illustration of it published in the *Universal magazine* (Figure 1), the eclipse of 1748, which was partial in London and total only north of the Firth of Forth, does not appear to have prompted great comment in the capital; the eclipse of 1737 — of which the southernmost edge of the path of totality ran along the banks of the Tyne river in northern England — excited only a little more notice.[15] In contrast, the eclipses of 1715, 1724, and 1764 stimulated a significant amount of commercial activity in and around London, providing opportunities for entrepreneurs to make money from lectures, pamphlets, instruments intended to illustrate the mechanics of the phenomenon, and a variety of accoutrements designed to enhance (and make safer) the public's observation of the events.

Astronomical broadsides played an especially important role in shaping the public understanding of the eclipses of 1715 and 1724, in part because the public had access to few other published sources that provided meaningful and useful information about these events. Compared to the variety and range of astronomical texts that were to become available to the English public beginning around the 1740s, relatively few astronomical works were published during the first quarter of the eighteenth century. Those that were available were generally of two types: introductory texts on "the use of the globes" published primarily for students, such as John Harris's *Description and use of the celestial and terrestrial globes* (first edition 1703) and Edward Well's *Young gentleman's astronomy, chronology, and dialling* (first edition 1712); and books derived from university lectures, such as William

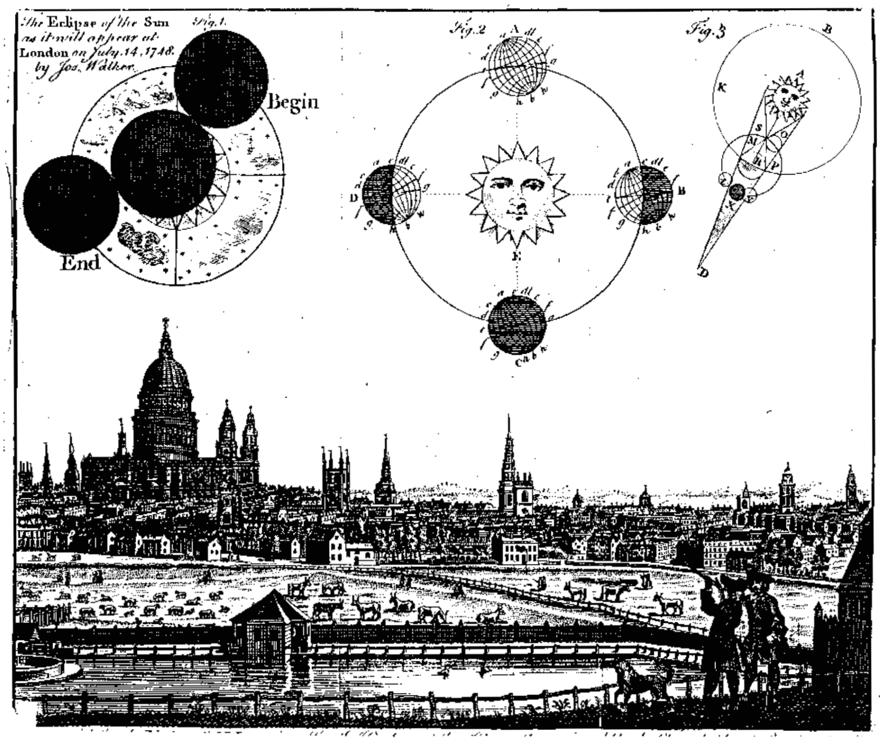

FIG. 1. "The cause of Eclipses and the Motion of the Earth Delineated" (1748). Originally published in the *Universal magazine*. Author's collection.

Whiston's *Astronomical lectures* (first English edition 1715), David Gregory's *Elements of physical and geometrical astronomy* (first English edition 1715), and John Keill's *Introduction to the true astronomy* (first English edition 1721). Among the very few works falling outside these types were William Derham's *Astrotheology: or a demonstration of the being and attributes of God from a survey of the Heavens* (first edition 1715), a sequel to his best-selling *Physico-theology*, and a work that can be considered "astronomical" only in the most general sense; and John Harris's *Astronomical dialogues between a gentleman and a lady*, an anglicized update of Fontenelle's *Dialogues on the plurality of worlds.*[16]

All of these works offered some discussion of eclipses. At the very least, each offered basic definitions of the different kinds of solar and lunar eclipses (partial, total, and annular), and some explanation of eclipses based on the movements of the Earth-Moon-Sun system, which illuminated the key distinction between a lunar and solar eclipse — that, while a lunar eclipse is caused by the shadow of the Earth moving across the Moon (thereby preventing the Moon from reflecting the Sun's light), a solar eclipse arises from the Moon itself blocking the light of the Sun from falling on a part of the Earth. Both basic texts on globes and the texts of university

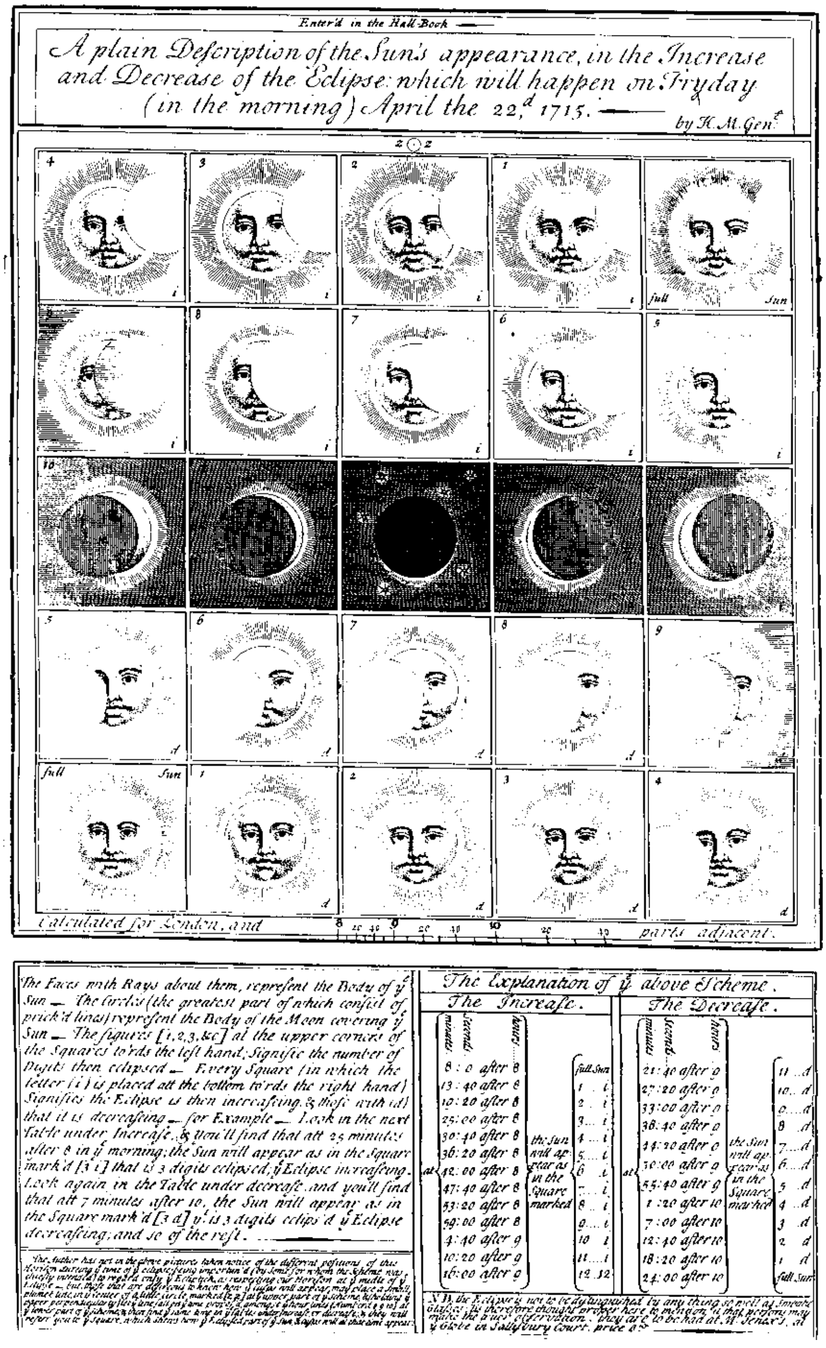

FIG. 2. Illustration of the solar eclipse of 1715. Adler Planetarium. 36 × 24 cm.

lectures offered mathematical discussions of the geometry of an eclipse (complete with figures), but (as might be expected) only Whiston, Gregory, and Keill outlined how one might go about calculating a given eclipse. At the other end of the spectrum, Derham and Harris avoided any mathematical discussion of eclipses; Derham noted the utility of eclipses to chronology and the determination of the longitude, while Harris characteristically digressed from his brief introduction to eclipses into poetry and flirtation. Perhaps the best account of eclipses available to the English reader in the early eighteenth century was either that written by John Flamsteed for publication in Jonas Moore's *Mathematicks* (a work published in 1680, and thus likely not widely available) or that found in William Whiston's 94-page *Calculation*

Text of Figure 2]

Enter'd in the Hall-Book

A plain Description of the Sun's appearance, in the Increase and Decrease of the Eclipse: which will happen on Fryday (in the morning) April the 22^{d}, 1715.

by H.M. Gen^{t}:

The Faces with Rays about them, represent the Body of y^{e} Sun. The Circles (the greatest part of which consist of prick'd lines) represent the Body of the Moon covering y^{e} Sun. The figures [1, 2, 3, &c] at the upper corners of the Squares to'rds the left hand; Signifie the number of Digits then eclipsed. Every Square (in which the letter (i) is placed att the bottom to'rds the right hand) Signifies the Eclipse is then increaseing: & those with (d) that it is decreaseing – for Example – Look in the next Table under Increase, & you'll find that att 25 minutes after 8 in y^{e} morning; the Sun will appear as in the Square mark'd [3 i] that is 3 digits eclipsed; y^{e} Eclipse increaseing. Look again in the Table under decrease, and you'll find that att 7 minutes after 10, the Sun will appear as in the Square mark'd [3 d] yt is 3 digits eclips'd y^{e} Eclipse decreaseing; and so of the rest.

The Author has not in the above pictures taken notice of the different positions of this Horizon dureing y^{e} time of y^{e} eclipse; being importun'd (by Some for whom the Scheme was chiefly intended) to regard only y^{e} Ecliptick, as respecting our Horizon at y^{e} midle of y^{e} Eclipse – but, those that are desireous to know how y^{e} Cusps will appear may place a small plumet line in y^{e} Center of a little Circle marked [z z] at ye upper part of y^{e} scheme, & (holding y^{e} paper perpendicularly) let y^{e} line fall on y^{e} time propos'd amongst y^{e} hour lines (Number'd 8, 9, 10) at y^{e} lower part of y^{e} scheme; & then find y^{e} same time in y^{e} Tables under Increase, or decrease & they will referr you to y^{e} Square; which shews how y^{e} Eclipsed part of y^{e} Sun & Cusps will at that time appear.

[Table with the times of the eclipse keyed to the illustrations; including the following times:]

8′0″ after 8^{h}	full Sun
...	
16′00″ after 9^{h}	12 digits eclipsed
...	
24′00″ after 10^{h}	full Sun

NB. the Eclipse is not to be distinguished by any thing so well as smoake Glasses; 'tis therefore thought proper here to mention it that persons may make the truer observation. they are to be had at M^{r}. Senex's, at y^{e} Globe in Sallisbury Court, price 6d.

I. Nutting Sculpsit

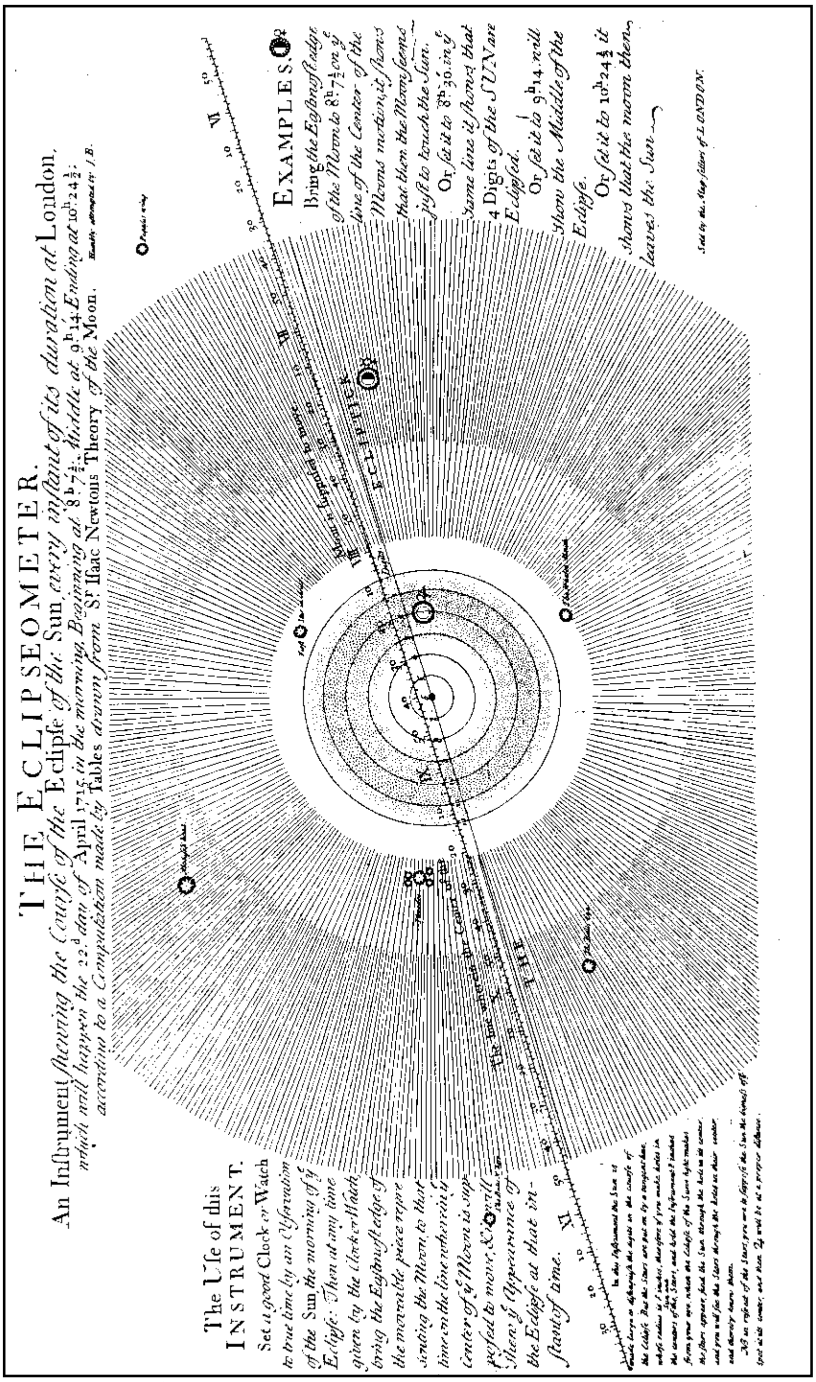

FIG. 3. "The Eclipseometer", a device that encouraged active participation in the solar eclipse of 1715. Oxford Museum of the History of Science.

of solar eclipses without parallaxes, which was published to coincide with the eclipse of 1724.[17]

However useful these texts may have been in explaining the cause (and perhaps the calculation) of an eclipse, none answered, or could answer, the questions uppermost in the minds of those members of the public anticipating an imminent eclipse: "Where and how can I see it, and what will it look like?" These books treated eclipses *in general*; they usually did not offer extended discussions and predictions of a *specific* eclipse. Astronomical broadsides filled that need. Some might merely offer minute-by-minute illustrations of what the eclipse would look like to observers at a given location (Figure 2); others could serve as instruments to encourage and facilitate the active participation of their purchasers in the observation of an eclipse (Figure 3). The best not only surveyed the astronomy of eclipses and suggested scientifically sanctioned interpretations of the phenomenon, they also offered predictions of the timing and the area to be covered by an upcoming eclipse, instructed users in safe eclipse-viewing, and provided directions for observing other astronomical objects during the eclipse. Thus, as accessible, attractive media

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Text of Figure 3]

THE ECLIPSEOMETER.

An Instrument *shewing the Course of the* Eclipse *of the* Sun, *every instant of its duration at* London, *which will happen the* 22^{d} *day of* April 1715 *in the morning, Beginning at* 8^{h} $7\frac{1}{2}'$: *Middle at* 9^{h} 14′: *Ending at* 10^{h} $24\frac{1}{2}'$; *according to a Computation made by* Tables *drawn from* S^{r}. Isaac Newtons Theory *of the* Moon. *Humbly attempted by J.B.*

The Use of this INSTRUMENT.

Set a good *Clock* or *Watch* to true time by an Observation of the *Sun*, the morning of y^{e} Eclipse: Then at any time given by the Clock or Watch, bring the Eastmost edge of the moveable piece representing the Moon, to that time on the line wherein y^{e} Center of y^{e} Moon is supposed to move, & it will shew y^{e} Appearance of the Eclipse at that instant of time.

EXAMPLES.

Bring the Eastmost edge of the Moon to 8^{h} $7\frac{1}{2}$ on y^{e} line of the Center of the Moons motion, it shows that then the Moon seems just to touch the Sun.
Or set it to 8^{h} 30′ in y^{e} same line it shows that 4 *Digits* of the SUN are Eclipsed.
Or set it to 9^{h} 14. will show the Middle of the Eclipse.
Or set it to 10^{h} $24\frac{1}{2}$ it shows that the moon then leaves the Sun.

In this Instrument the Sun is made large to distinguish the digits in the course of the Eclipse: But the Stars are put on by a tangent line whose radius is 8 inches; therefore if you make holes in the centers of the Sun and Stars, and hold the Instrument 8 inches from your eye, when the Ellipse of the Suns light makes the stars appear, find the Sun through the hole in its center, and you will see the Stars through the holes in their center, and thereby know them.

NB in respect of the Stars, you are to suppose the Sun the bigness of y^{e} spot at its center, and then [Jupiter] will be at a proper distance.

Sold by the Map sellers of LONDON.

providing up-to-date scientific information about eclipses, these broadsides offer a unique insight into the ways in which the English astronomical community of the first quarter of the eighteenth century encouraged, shaped, and benefited from the public's interest in astronomy.

1. A "SUDDAIN DARKNESS": EDMOND HALLEY AND THE PUBLIC ASTRONOMY OF ECLIPSES

The solar eclipse of 22 April 1715 (3 May according to the new calendar) provided the first opportunity for the marketers of scientific commodities to package a major astronomical event. John Senex took particular advantage of the anticipated eclipse, publishing three different broadside predictions of the event, two with texts by William Whiston, and one with a text by Edmond Halley. Halley's broadside, *A Description of the Passage of the Shadow of the Moon over England* and Whiston's first print, *A Calculation of the Great Eclipse of the Sun*, were advertised twice during March and April of 1715 in the *London Gazette*. The second advertisement, appearing in the edition dated 2–5 April 1715 (old style), asserted that an extraordinarily long time had passed since such an event had been visible from London:

> This Day is Published a new Edition of Mr. Professor Halley's Description of the total Eclipse of the Sun on Friday the 22d Day of this Instant April in the Morning, when by reason of the sudden Darkness the Stars will be visible about the Sun, the like Eclipse having not been seen in the Southern Parts of Great Britain for above 500 Years. N.B. The Map shews every part of England over which the total Darkness will pass, and may be sent by the Post for the same Charge as a single Letter. Printed for J. Senex in Salisbury-Court, and William Taylor at the Ship in Pater noster-row. Where may be had Mr. Whiston's Calculation of the Eclipse; also his Astronomical Lectures, being a Survey of the Heavens.[18]

This advertisement demonstrates that Senex made good use of the opportunity presented by this dramatic event to expand the audience for astronomy, and so the market for astronomical commodities, in particular, by adopting advertising strategies designed to target markets outside the bounds of both London and the community of astronomical cognoscenti. First, he promoted orders from the provinces; the advertisement promised a map of "every part of England" over which the eclipse would be total (without revealing exactly where those areas were), and further noted that curious provincial customers could receive the map by post for a nominal cost. Second, he used the occasion to advertise a work on general astronomy — in this case, his newly-published English edition of Whiston's *Astronomical lectures*, an introductory collection originally intended, as the subtitle of the work noted, "For the Use of young Students in the University".[19] Senex's insertion into the notice of the print of an advertisement for Whiston's book is a typical eighteenth-century advertising strategy, and both of the prints mentioned in this advertisement referred to other products available to customers through Senex's business, including most particularly "the Newest and Correctest Maps, and Globes of 3, 9, 12, and 16 Inches Diameter, at moderate prices".[20]

Although the advertisement mentioned Whiston's broadside *Calculation of the Great Eclipse of the Sun* (discussed below), it focused on Halley's *A Description of the Passage of the Shadow of the Moon over England*, which had a broader appeal. Engraved by Senex and sold by him for 6 pence, Halley's *Description* (Figure 4) displayed a map of England with Halley's prediction of the path over which the eclipse would be total and partial superimposed.[21] In the text attached to the map, and an account of the eclipse subsequently published in the *Philosophical transactions*, Halley expressed two goals in publishing this print. First, he sought to distance the astronomical event from its unfortunate timing. The Hanoverian succession of 1714 had provoked a period of civil unrest in London that became particularly serious in the spring of 1715.[22] In this climate, the prospect of a solar eclipse — with its inevitable astrologically-inspired political interpretations — must have been alarming to many. Halley consequently began his text with the reassurance that the eclipse was a purely astronomical event, and not a political portent:

> The like Eclipse having not for many Ages Been seen in the Southern Parts of Great Britain, I thought it not improper to give the Publick an Account thereof, that the suddain darkness wherein the Starrs will be visible about the Sun, may give no surprize to the People, who would, if unadvertized, be apt to look upon it as Ominous and to Interpret it as portending evill to our Sovereign Lord King George and his Government, which God preserve. Hereby they will see that there is nothing in it more than Natural, and nomore than the necessary result of the Motions of the Sun and Moon.[23]

Halley's fear that "the People" might interpret the eclipse as a bad omen for the new king was not misplaced; the author of a poem published in commemoration of the eclipse expressed similar concern over its timing, noting with relief that it just missed the 23 April celebration in remembrance of St George, the patron saint of England:

> But, Interposing Globe, we can't forbear,
> Of Timing this Eclipse to tell thy awful care;
> Surely Thou did'st our Calendar inspect,
> And thereby prudently thy course direct,
> As not to blemish *Albion's* day of Fame,
> Doubly by us rever'd, for SAINT and NAME.
> For our Great Monarch's sake, thy sullen shade
> On fam'd St. GEORGE'S day durst not invade
> This Realm, tho' near approaches thou hadst made.[24]

George I and the House of Hanover survived the eclipse. However, as one English author subsequently noted, not all kings were as lucky; "The Sun King", France's Louis XIV, died in August 1715.[25]

FIG. 4. Halley's broadside with his prediction of the path of the solar eclipse of 1715. Royal Astronomical Society. 43 × 27 cm.

Halley's second purpose in publishing the *Description* was to invite "the Curious" to observe the eclipse, and report their observations back to him, so that he would be able to determine "the Situation and dimension of the Shadow".[26] He explained after the event in the *Philosophical transactions* that no total solar eclipse had been visible from London since 1140:

> The Novelty of the thing being likely to excite a general Curiosity, and having found, by comparing what had been formerly observed of Solar Eclipses, that the whole Shadow would fall upon England, I thought it a very proper Opportunity to get the Dimensions of the Shade ascertained by Observation;

Text of Figure 4]

A Description of the Passage of the Shadow of the Moon over England, *In the Total Eclipse of the SUN on the 22d Day of April 1715 in the Morning*

The like Eclipse having not for many Ages Been seen in the Southern Parts of Great Britain, I thought it not improper to give the Publick an Account thereof, that the suddain darkness wherein the Starrs will be visible about the Sun, may give no surprize to the People, who would, if unadvertized, be apt to look upon it as Ominous and to Interpret it as portending evill to our Sovereign Lord King George and his Government, which God preserve. Hereby they will see that there is nothing in it more than Natural, and nomore than the necessary result of the Motions of the Sun and Moon; And how well those are understood will appear by this Eclipse.

According to what has been formerly Observed, compared w^th our best Tables, we conclude y^e Center of y^e Moon's shade will be very near y^e *Lizard* point, when it is about 5 min: past Nine at *London*; and that from thence in Eleven minutes of Time, it will traverse y^e whole Kingdom, passing by *Plymouth*, *Bristol*, *Glocester*, Daventry, *Peterborough*, & Boston, near w^ch it wil leave y^e Island: On each side of y^e Tract for about 75 Miles, the Sun will be Totally darkned; but for less & less Time, as you are nearer those limits, wch are represented in y^e Scheme, passing on y^e one side near *Chester*, Leeds, and *York*; and on y^e other by *Chichester*, Gravesend, and Harwich.

At *London* we Compute the Middle to fall at 15 min: past 9 in y^e Morning, when 'tis dubious whether it will be a Total Eclipse or no, *London* being so near y^e Southern limit. The first beginning will be there at 7 min: past Eight, and y^e end at 24 min: past Ten. The Ovall figure shews y^e space y^e Shadow will take up at y^e Time of the Middle at *London*; And its Center will pass on to y^e Eastwards, with a Velocity of nearly 30 Geographical Miles in a min: of Time.

NB. The Curious are desired to Observe it, and especially the duration of Total Darkness, with all the care they can; for therby the Situation and dimensions of the Shadow will be nicely determined; and by means therof we may be enabled to Predict the like Appearances for y^e future, to a greater degree of certainty than can be pretended to at present, for want of such Observations.

By their humble Servant
Edmund Halley

Sold by I. Senex, at the Globe in Salisbury Court, near Fleetstreet; who makes and sells y^e Newest and Correctest Maps, and Globes of 3, 9, 12, and 16 Inches Diameter, at moderate Prices.

Sold also by William Taylor at the Shop in Paternoster Row

Entered in the Hall Book

> and accordingly, I caused a small Map of England, describing the Track and Bounds thereof, to be dispersed all over the Kingdom, with a Re-quest to the Curious to observe what they could about it, but more especially to note the Time of Continuance of total Darkness, as requiring no other Instrument than a Pendulum Clock with which most Persons are furnished....

Armed with observations from volunteers throughout the country, Halley was confident that he would be able "to establish several of the Elements of the Calculus of Eclipses, so as for the future we may more securely rely on our Predictions".[27]

Although Halley separated his two stated objectives for publishing the map — that of rationalizing the eclipse and that of obtaining its dimensions with the aid of a nationwide network of volunteer observers — these objectives complemented each other. By soliciting observations, Halley's print presented the eclipse as a public, participatory event, thereby making it seem less like a supernatural disaster happening "to" the people of Britain; offering a prediction of the time of the eclipse merely reinforced the fact that the astronomical community had mastered the phenomenon.[28] This strategy placed the eclipse firmly within the empirical, hands-on experience of science emerging in the lecture theatres and instrument shops during the second decade of the century. It also suited the unique character of the phenomenon; since an eclipse cannot be duplicated at will by lecturers, the more who were encouraged to observe it — and the more who were properly primed to understand it as a natural event — the better for the advancement of Newtonian science. Even those lacking either the instruments or the skill to observe the eclipse with the precision necessary to contribute to Halley's "Calculus" could nevertheless have understood the message underlying Halley's request: the eclipse is an occasion not for fear, but for the advancement of astronomy.

While the message, layout, and cost of Halley's *Description* made it broadly accessible, Halley's declaration in the *Philosophical transactions* that he assumed that most of his volunteer observers would have a pendulum clock available to time the eclipse defined the segment of society from which he expected the most accurate eclipse observations. Lorna Weatherill's study of British probate records indicates (not surprisingly) that the best indicators of clock ownership were wealth, education, and residence in London; in 1715, 52% of all London households owned clocks, while clocks might be found in fully 90% of the homes of wealthy tradesmen and merchants living in London. In contrast, only 33% of the households of the entire country possessed clocks, with the majority found in the homes of professionals, the gentry, and those in high-status trades.[29] Thus, not only the technical complexities of eclipse observations, but also its material demands, selected the volunteer observers likely to produce data of use to Halley.

Nevertheless, Halley discovered that for some would-be surrogates, their enthusiasm for contributing to the refinement of eclipse theory exceeded their resources; not everyone who sent observations to Halley had good clocks available to them. Halley commented in his account of the eclipse published in the *Philosophical* *transactions* that observers at Barton in Northamptonshire and King's Walden in Hertfordshire who were furnished with "good Pendulum-Clock(s)" measured the time of totality to be 3′ 53″ and 3′ 52″, respectively. In contrast, observers who reported from Plymouth, Exeter, Weymouth, Daventry, Northampton and Lynn Regis reported that totality lasted four minutes or more, leading Halley to suspect that they had relied on "pocket Minute-Watches" in making their measurements.[30] But, in the table of data he published in the *Philosophical transactions*, Halley made no distinction between the observations based on his evaluation of their quality or reliability; rather, he expressed his gratitude to "all those who have been willing to promote our Endeavours to perfect the Doctrine of Eclipses". Moreover, he declared that the sum result of their efforts was something of which they should be proud: "this is the first Eclipse of this kind that has been observed with the Attention and Dignity of the Phenomenon requires (*sic*) ...."[31]

Readers of the *Philosophical transactions*, like the 20-some volunteers who contributed their observations to Halley, might have been expected to aid in the advancement of eclipse theory. But, in the aftermath of the eclipse, Halley also attempted to reach beyond this limited audience to a wider public. Once again, he turned to the broadside as his medium (Figure 5). In a print evidently published some months after the event, Halley provided a corrected path for the eclipse, and acknowledged the contributions of his volunteer observers:

> Since the Publication of our Predictions of this Eclipse has had the desired effect, and many curious Persons have been excited thereby to communicate their Observations from most parts of the Kingdom, we thought it might not be unacceptable to represent after the same manner the passage of the Shade, as it really happened; whereby it will appear that tho' our Numbers pretend not to be altogether perfect yet the correction they need is very small.[32]

In that it provides both the corrected path of the 1715 eclipse, and the predicted path of the forthcoming eclipse of 1724, Halley's post-eclipse print, *A Description of the Passage of the Shadow of the Moon over England as it was Observed in the late Total Eclipse of the SUN April 22d 1715*, serves as a material link between the two events. Although it lacked the obvious political connotations of the 1715 eclipse, the eclipse of 1724 nevertheless provided the community of scientific entrepreneurs with another opportunity to shape the public's understanding of eclipses — and another opportunity to make money. Thus, in November 1723, in anticipation of the eclipse of 1724, Senex reprinted Halley's nine-year-old broadside, publishing it under the title *A Description of the Passage of the Shadow of the Moon over England In the Total Eclipse of the Sun on the 11th day of May 1724 in the Evening. Togather* (sic) *with the Passage of the Shadow as it was Observed in the last Total Eclipse of 1715*, and amending the print to make note of Halley's new status as Astronomer Royal.[33]

For this eclipse, however, Senex also attempted to reach an audience beyond the Channel, engraving and publishing another map displaying Halley's prediction: *A*

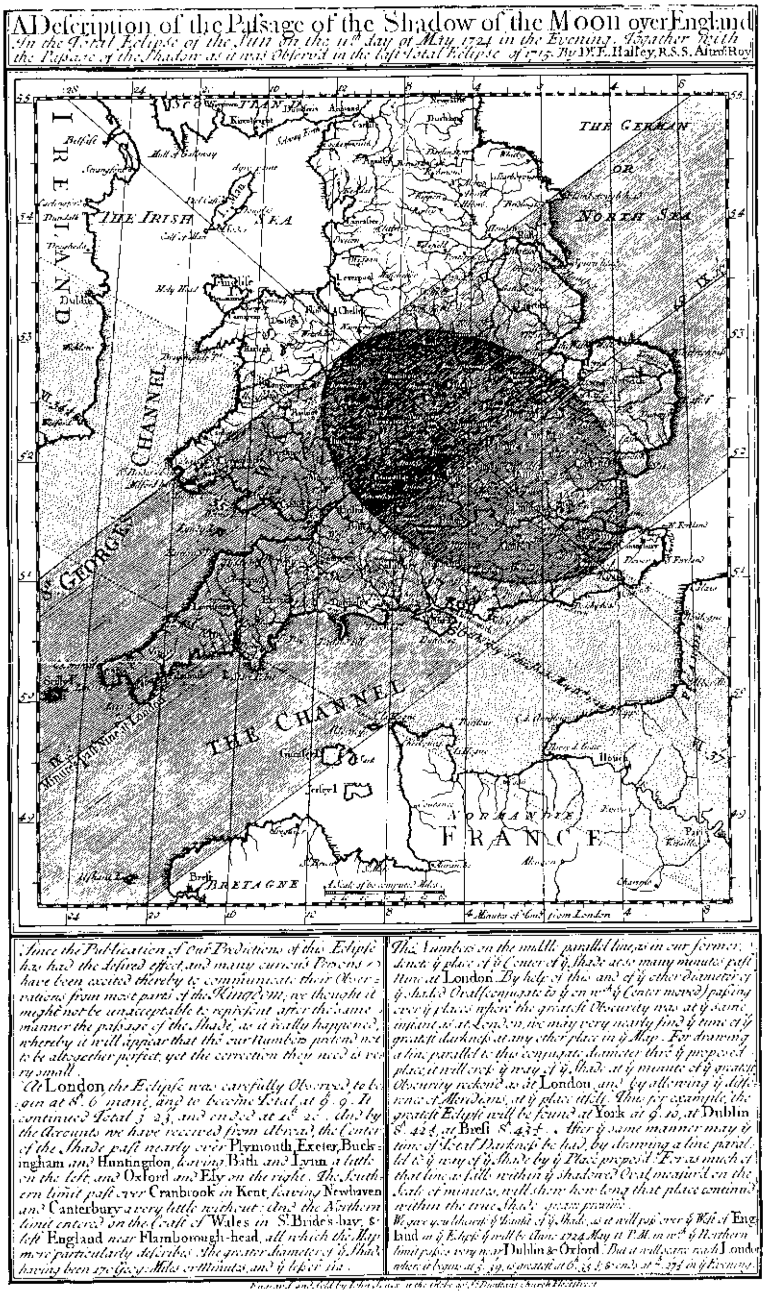

FIG. 5. Halley's broadside with his retrospective description of the path of the solar eclipse of 1715 and his prediction of the path of the eclipse of 1724. Science Museum Library, London. 41 × 27 cm.

Description of the Passage of the Shadow of the Moon over Europe, as it may be expected May 11th 1724 in the Evening (Figure 6). The intent to target an international audience is suggested not only by the geographical scope of the map — it shows the path of eclipse extending from western Ireland through England, France, Switzerland, and northern Italy to Venice — but also by the brief text appended to the map, which compared this event not to the eclipse of 1715, but to a solar eclipse that had occurred in 1706. In the *Philosophical transactions* account of the 1715 eclipse, Halley had expressed some frustration with Continental astronomers, who had (he believed) neglected properly to observe the earlier event. After noting his efforts to ascertain the northern and southern limits of the 1715 shade, he continued,

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Text of Figure 5]

A Description of the Passage of the Shadow of the Moon over England In the Total Eclipse of the Sun on the 11th day of May 1724 in the Evening. Togather with the Passage of the Shadow as it was Observed in the last Total Eclipse of 1715. By *D^{r}. E. Halley, R.S.S. Astro$^{r.}$Roy^{l}*

Since the Publication of our Predictions of this Eclipse has had the desired effect, and many curious Persons have been excited thereby to communicate their Observations from most parts of the Kingdom; we thought it might not be unacceptable to represent after the same manner the passage of the Shade as it really happened; whereby it will appear that thô our Numbers pretend not to be altogether perfect; yet the correction they need is very small.

At *London* the Eclipse was carefully Observed to begin at 8^{h} 6′ manè and to become Total at 9^{h} 9′. It continued Total 3′23″ and ended at 10^{h} 20′. And by the Accounts we have received from Abroad, the Center of the Shade past nearly over *Plymouth*, *Exeter*, *Buckingham*, and *Huntingdon*, leaving *Bath* and *Lynn* a little on the left and *Oxford* and *Ely* on the right. The Southern limit past over *Cranbrook* in *Kent*, leaving *Newhaven* and *Canterbury* a very little without: and the Northern limit entered on the Coast of *Wales* in *S^{t}. Bride's-bay* & left *England* near *Flamborough-head*, all which the Map more particularly describes. The greater diameter of y^{e} Shade having been 170 Geog. Miles or Minutes, and y^{e} lesser 110.

The Numbers on the middle parallel line, as in our former, denote y^{e} place of y^{e} Center of y^{e} Shade at so many minutes past Nine at *London*. By help of this and of y^{e} other diameter of y^{e} shaded Oval (conjugate to y^{t} on w^{ch} y^{e} Center moved) passing over y^{e} places where the greatest Obscurity was at y^{e} same instant as at London, we may very nearly find y^{e} time of y^{e} greatest darkness at any other place on y^{e} Map. For drawing a line parallel to this conjugate diameter thrô y^{e} proposed place, it will cross y^{e} way of y^{e} Shade at y^{e} minute of y^{e} greatest Obscurity reckon'd as at *London*, and by allowing y^{e} difference of Meridians, at y^{e} place itself. Thus for example, the greatest Eclipse will be found at *York* at 9^{h} 10′, at *Dublin* 8^{h} 42$\frac{1}{2}$′, at *Brest* 8^{h} 43$\frac{1}{2}$′. After y^{e} same manner may y^{e} time of Total Darkness be had, by drawing a line parallel to y^{e} way of y^{e} Shade by y^{e} Place proposed: For as much of that line as falls within y^{e} shadowed Oval, measur'd on the Scale of minutes, will shew how long that place continu'd within the true Shade. quam proxime

We give you likewise y^{e} Transit of y^{e} Shade, as it will pass over y^{e} West of *England* in y^{e} Eclipse y^{t} will be Anno 1724 May 11 P.M. in w^{ch} y^{e} Northern limit passes very near *Dublin* & *Oxford*. But it will scarce reach *London* where it begins at 5^{h} 39′, is greatest at 6^{h} 35$\frac{1}{2}$′, & ends at 7^{h} 27$\frac{1}{2}$′ in y^{e} Evening.

Engraved and Sold by Iohn Senex at the Globe ag^{t} St Dunstans Church Fleetstreet

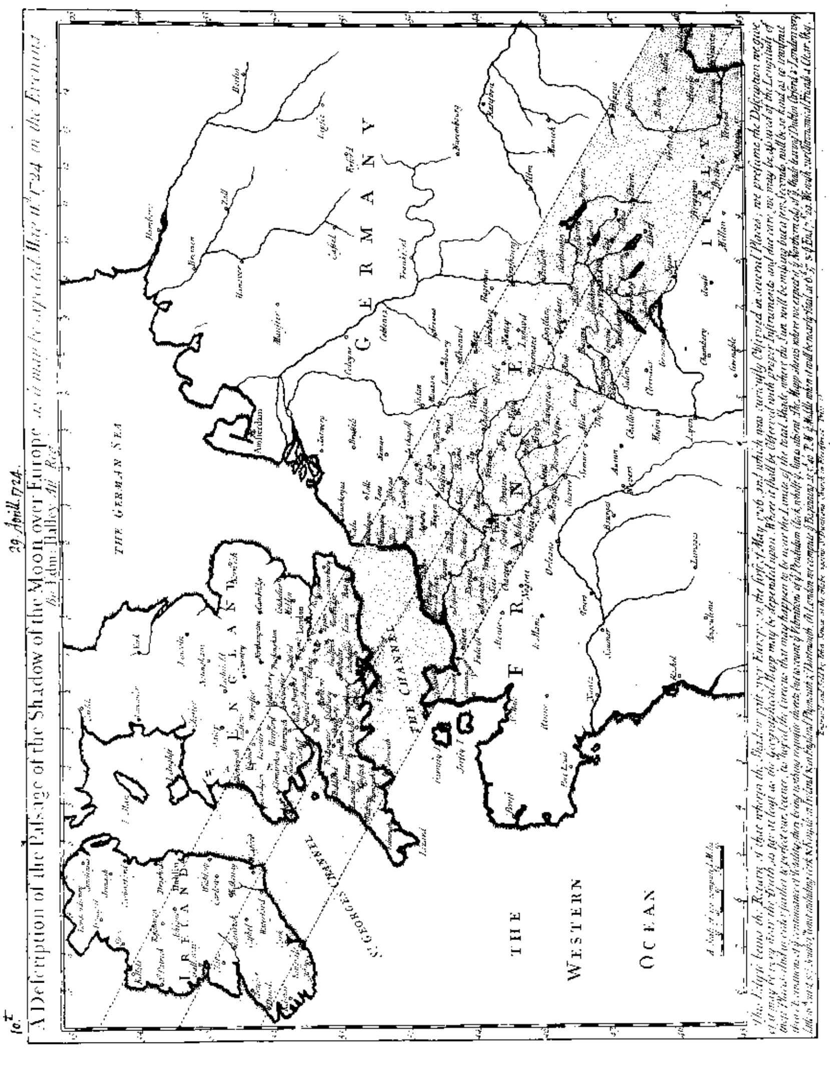

FIG. 6. Halley's second broadside with his prediction of the path of the solar eclipse of 1724. Houghton Library, Harvard University. 37 × 48 cm.

"we should have been glad the *French Astronomers* had done the like for the Total Eclipse that past over *Languedoc*, *Provence*, and *Dauphiny* on the first of *May* 1706".

Senex's publication of Halley's *Description of the Passage of the Shadow of the Moon over Europe* may thus be seen as an effort to succeed internationally where they had succeeded on a national level in 1715. Once again, the broadside extended an invitation to dispatch observations to Halley, but this time, rather than offering the refinement of eclipse theory as the sole objective, Halley also declared the data to be of importance for another reason:

> This Eclipse being the return of that wherein the Shadow past over Europe on the first of May 1706, and which was curiously Observed in several Places; we presume the Description we give of it may be very near the Truth, as far at least as the Geographical Mapp may be depended upon. Where it shall be Observed with proper Instruments and due care, we may be assured of the Longitude of those Places; And in order further to perfect our Science, 'tis hoped the Curious that may happen to be near the Limits of the total Shade, where the Sun will be missing but a few Seconds, will be so kind as to transmit their Observations of y^{e} continuance of Totality; there being nothing requisite thereto, but to count y^{e} Vibrations of y^{e} Pendulum Clock, whilst y^{e} Sun is absent. [34]

In fact, Halley's science of eclipses needed perfecting. He had proudly noted in 1715 that his prediction of that April's eclipse required little correction, but the actual path differed from the predicted path by about 20 miles.[35] A similar error

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Text of Figure 6]

A Description of the Passage of the Shadow of the Moon over Europe, *as it may be expected May 11th 1724 in the Evening. By* Edm: Halley, *Ast: Reg.*

This Eclipse being the Return of that wherin the Shadow past over Europe on the first of May 1706, and which was curiously Observed in several Places; we presume the Description we give of it may be very near the Truth, as far at least as the Geographical Mapp may be depended upon. Where it shall be observed with proper Instruments and due care, we may be assured of the Longitude of those Places; And in order further to perfect our Science, 'tis hoped the Curious that may happen to be near the Limits of the total Shade, where the Sun will be missing but a few Seconds, will be so kind as to transmit their Observations of y^{e} continuance of Totality; there being nothing requisite thereto, but to count y^{e} Vibrations of y^{e} Pendulum Clock, whilst y^{e} Sun is absent. The Mapp shews where we expect it, y^{e} Northern edg of y^{e} Shade leaving Dublin Oxford & London very little wthout it, & y^{e} Southern limit including Cork & Kinsale in Ireland, & in England Plymouth & Dartmouth. At London we compute y^{e} Beginning at 5^{h} 40′ P.M. y^{e} Middle when it will be nearly Total at 6^{h} 37′ & y^{e} End 7^{h} 29′. We wish our Astronomical Friends a Clear Sky.

Engrav'd and Sold by Iohn Senex at the Globe against St. Dunstans Church in Fleetstreet. Price 1s.

arose in Halley's prediction of the 1724 eclipse: Halley's map predicted a path that would pass just to the west of London, with the eclipse showing totality at Reading and Windsor. In fact, he was off by some 25 miles, an error that did his reputation little good. According to James Logan, visiting England from Philadelphia, Halley's inaccuracy frustrated "vast numbers" of would-be observers, who travelled west of London only to be greeted by a view of a partial eclipse (and that only visible through the clouds). Logan himself attempted to view the eclipse from Windsor, but discovered "it was not total there, as Dr. Halley then the Kings Astronomer had by his Map given the world to expect". Logan's disappointment was exacerbated by the fact that a broadside by William Whiston had offered another prediction, which was, according to Logan, more accurate; he noted in frustration on the corner of his copy of Whiston's broadside that its prediction was "by much the truest".[36]

2. PROPHECY AND PROFITS: WILLIAM WHISTON AND THE BUSINESS OF ECLIPSES

Halley and Whiston had competed for the mastery of an eclipse before. In 1715, both had offered their predictions of the eclipse in broadsides published by John Senex; recall that Senex had advertised Whiston's *Calculation of the great eclipse of the Sun* in the same newspaper advertisements that had publicized Halley's eclipse map. But, while both astronomers produced prints for publication by Senex, the prints they produced, and the objectives that shaped those prints, differed greatly. In 1715, Halley's professional star was on the rise. Elected FRS in 1678 at the age of 22, Halley had at various times in his life served Britain and science as a sea captain, astronomer, diplomat, bureaucrat, secretary of the Royal Society, and Savilian Professor of Geometry at Oxford; at Flamsteed's death in 1720, Halley replaced him as Astronomer Royal, a post he held for 22 years. In contrast, in 1715, Whiston's fortunes were in decline. Although he had held a position of some prestige — the Lucasian chair of mathematics at Cambridge (to which he was appointed as Newton's successor in 1701) — his expulsion from Cambridge in 1710, a consequence of his imprudently vociferous Arianism, had all but destroyed his chances of future preferment. Of course, Whiston's heretical beliefs made election to the Royal Society impossible.[37] Thus, after 1710, Whiston was forced to support himself and his family through longitude projects, lecturing, writing, teaching, and the generosity of patrons.[38]

Consequently, the publication of predictive eclipse broadsides served quite different purposes for Whiston than it had for Halley. Neither his 1715 nor his 1724 print reveals any hint that Halley sought financial profit from the eclipse business; instead, Halley apparently tried to use eclipses as opportunities to enhance his status as a leader and organizer of the astronomical community, first nationally and then internationally. In 1715, he may also have felt compelled to ingratiate himself with the new regime, in order to distance himself from his rather shady past as a Tory.[39] In contrast, both of Whiston's two 1715 prints and his 1724 broadside feature prominent advertisements for several of his other products (relating to both general astronomy and the eclipse itself), suggesting his financial interest in whetting the public's appetite for astronomical commodities. In short, it seems that while Halley's primary objective for contributing to the eclipse business was to increase his scientific prestige, Whiston's interest lay primarily in the profits of public astronomy.

His commercial interest in popular astronomy did not begin in 1715. In 1712, Whiston, along with John Senex, had pioneered the production of broadsides intended for the public presentation of astronomy. His *Memoirs* records his collaboration with Senex in the production of a large-format, general astronomy print:

> About the same Year 1712, I published a *Scheme of the Solar System*, with the Orbits of 21 Comets; in a large Sheet of Paper, engraved on Copper, by Mr. *Senex*, *Price* 2s. 6d. Which Scheme has been of great Reputation and Advantage among the curious ever since.[40]

In fact, Whiston's *Scheme* proved to be an extraordinarily long-lived item. Senex himself probably published two editions, which may be distinguished by their advertisements for his globes; although these editions are not dated, as many as fifteen years may have separated their publication.[41] Just before Senex's death in 1740, the print was advertised in Thomas Wright's textbook *The use of the globes: or, the general doctrine of the sphere*; after his death, the plate for this print — like the plates and jigs for his globes — was evidently sold to another member of the trade, probably either John Bowles or Robert Sayer, who republished it in partnership around 1760. An epitome of Whiston's *Scheme*, entitled *The Newtonian System of Sun, Planets, and Comets* was also published by Senex around 1723; this print was republished one hundred years later by the instrument maker Francis West.[42]

The persistence of these prints suggests the profitability of their production for their publishers. Engraving in copper plate required a considerable investment of both money and time.[43] Senex evidently found the investment in engraving and publishing astronomical prints profitable, as he made that investment a dozen times over his very successful career. Similarly, Bowles and Sayer — neither of whom seemed to have had an interest in the production of scientific commodities other than maps — evidently thought that the republication of Whiston's *Scheme* some fifty years after it was engraved would prove more profitable than merely melting down the plate.[44]

The text of the *Scheme* reveals Whiston's penchant for superimposing religious (and consequently political) interpretations onto astronomical and meteorological events, both in his publications and in the coffee-house lectures he began giving in London after 1710.[45] Whiston considered comets especially potent portents; in the *Scheme*, he suggested that comets could bring about "Deluges and Conflagrations" on planets that passed through their tails, thereby serving as "the instruments of Divine vengeance upon the Wicked Inhabitants" of those unfortunate worlds.[46] In 1714, Whiston proposed a specific instance of this, extending a theory proposed earlier by Halley and himself to the effect that the Noachian deluge had been caused by a collision between the Earth and a comet; he further suggested that a similar

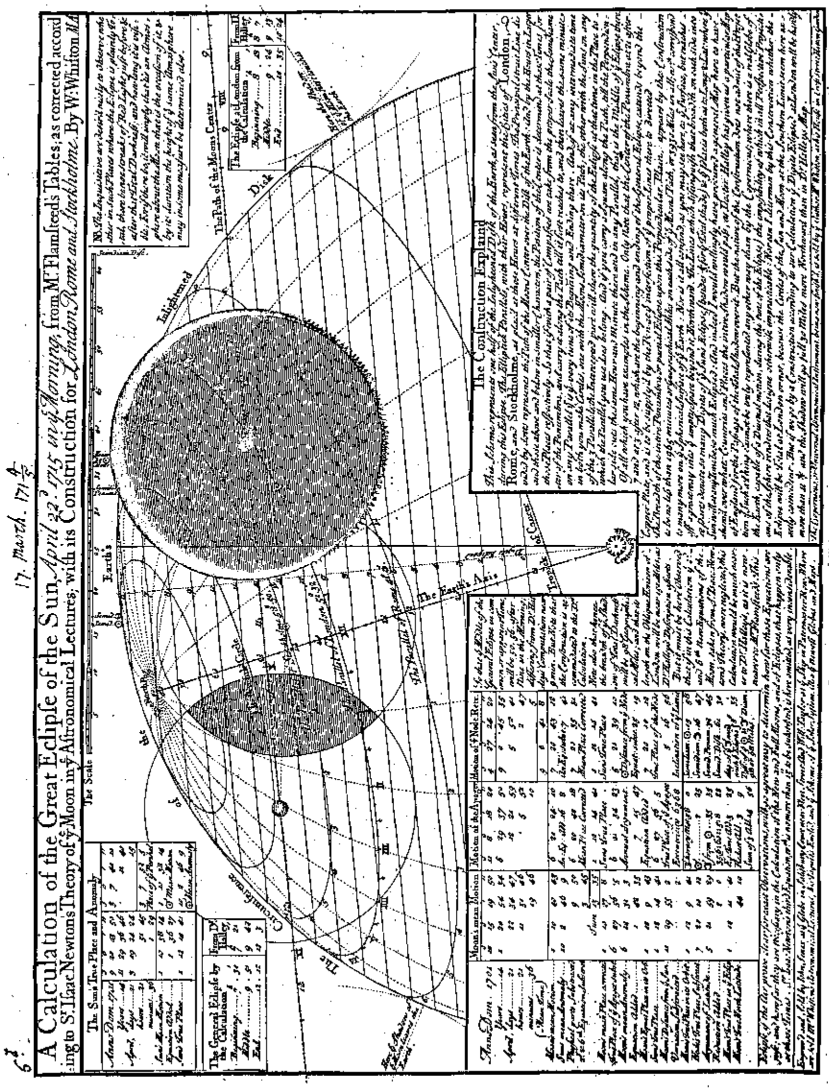

FIG. 7. Whiston's *A Calculation of the Great Eclipse of the Sun, April 22d 1715*. Houghton Library, Harvard University. 27 × 41 cm.

Text of Figure 7]

A Calculation of the Great Eclipse of the Sun, *April 22ᵈ 1715 in yᵉ Morning*, from Mʳ. Flamsteed's Tables; as corrected according to Sʳ. Isaac Newton's Theory of yᵉ Moon in yᵉ Astronomical Lectures; with its Construction for *London Rome and Stockholme*. By W: Whiston *M.A.*

Upper left, top: [Table: "The Sun's True Place and Anomaly" for April 22 1715]

Upper right, top: NB. The Inquisitive are desir'd nicely to Observe whether in such Places where the Eclipse is plainly Total, there be not streaks of Red Light just before & after that Total Darkness; and how long it is visible; For if there be, it will imply that 'tis an Atmosphere about the Moon that is the occasion of it, & by its duration the height of yᵉ same Atmosphere may in some measure be determined also.

Upper left, bottom:

The General Eclipse by the Calculation			From Dʳ. Halley	
Beginning	7^h	30′	7^h	21′
Middle	9^h	51′	9^h	42′
End	12^h	12′	12^h	3′

Upper right, bottom:

The Eclipse at London from the Calculation			From Dʳ. Halley	
Beginning	8^h	18′	8^h	7′
Middle	9^h	24′	9^h	13′
End	10^h	35′	10^h	24′

Bottom left, table:
["Moon's mean Motion", "Motion of the Apogee", "Motion of yᵉ Node Retr.", and Whiston's calculation of the Eclipse]

Bottom left, text:
So that yᵉ Middle of the General Eclipse in common or apparent Time will be 50′ 56″. after Nine in the Morning; differing from Dʳ. Halley's Computation near 9 min. But Note that the Construction is accommodated to the Dʳˢ. Calculation.

Note also that hence the breadth of yᵉ Shadow of Total Darkness will be 98 Geographical Miles; and that its length on the Oblique Horizon of London will be near 150 Miles, as Dʳ. Halley's Description asserts.

But it must be here Observed that if in this Calculation yᵉ 2ᵈ and 6ᵗʰ New Equations of the Moon, taken from Sʳ. Isaac Newton's Theory, were neglected, this Calculation would be much nearer to Dʳ. Halley's, as it is now nearer to Mʳ. Flamsteed's. This Eclipse, if the Air prove clear for exact Observations, will go a great way to determin how far those Equations are just; and how far they are necessary in the Calculation of the New and Full Moons, and of Eclipses, that happen only at those Times. Sʳ. Isaac Newton's third Equation, wᶜʰ is no more than 13″ to be subtracted, is here omitted, as very inconsiderable.

Bottom right, text:

The Construction Explain'd

This Scheme represents one half of the Inlightened Disk of the Earth, as seen from the Sun's Center during this Eclipse. The Elliptick Parallels, with their Hours, represent the Cities of *London*, *Rome*, and *Stockholme*, as plac'd at those Hours at different Times. The Principal strait Line divided by dotts represents the Path of the Moons Center over the Disk of the Earth: And by the Hours in Larger and those above and below in smaller Characters, the Position of the Center is determind at those Times for those Places respectively. So that if with a pair of Compasses we take from the proper Scale the Semidiameter of the Penumbra, and carry it along the Path till it first reaches to, and then leaves the same minute on any parallel yᵗ is yᵉ very time of its Beginning and Ending there. And if at any intermediate time in both you make Circles, one with the Moons Semidiameter on its Path; the other with the Suns on any of the 3 Parallels; the Intercepted part will shew the quantity of the Eclipse at that time in event in the future would precipitate the end of the world.[47] Between 1715 and 1717 a series of remarkable celestial phenomena occurred, including, in addition to the eclipse, the appearance of a nova, an unusually cold winter, and a particularly intense aurora, all of which, according to Whiston's coffee-house lectures, "were unequivocal warnings to mankind about the apocalypse and manifested divine discontent with a corrupt and sinful humanity".[48]

Near the end of his life, eclipses came to occupy a special place in Whiston's cosmology, as he felt that they were connected to the fulfilment of biblical prophecies.[49] In contrast to Halley, who at the time cautiously dismissed speculation that the 1715 eclipse had any political meaning, thirty-four years after the event Whiston celebrated the eclipse as signalling the end of the uncomfortable conservatism of the Stuart regime (which had certainly made his own professional and personal life difficult): "This Eclipse of the Sun, tho' I then did not think of it, appears now to have been a Divine Signal for the End of over-bearing Persecution in two of the ten idolatrous and persecuting Kingdoms, which arose in the fifth Century, in the *Roman*

Text of Figure 7, continued]

the Place to which the Parallel you use does belong. And if you carry a Square along the Path, till the Perpendicular side cuts the same Hour and Minute there and in any Parallel, that is the Middle of the y^{e} Eclipse there. Of all which you have examples in the Scheme. Only Note that the Center of the Penumbra at 21′ after 7 and at 3′ after 12, which are the beginning and ending of the General Eclipse, extends beyond the Copper Plate, and is to be supply'd by the Pen at y^{e} intersection of y^{e} proper Lines there to directed.

The Breadth of the intire Penumbra or partial Eclipse upon this Perpendicular Plain, appears by the Construction to be no less than 1965 minutes or Geographical Miles on each side of y^{e} Moons Path, or 3930 Miles in all; w^{ch} correspond to many more on y^{e} Spherical Surface of y^{e} Earth: Nor is it all confin'd, as you may see here, to y^{t} Surface, but reaches off a great way into y^{e} empty Space beyond it, Northward. The Lines which distinguish that breadth on each side into 12 Parts denote so many Digits of y^{e} Sun's Eclipse, (besides $\frac{1}{3}$ for y^{e} Total shade) & y^{t} places both as to Long: and Lat: where y^{e} Sun will at any Time be so much Eclipsed: And indeed I would willingly have procured a general Map here to have shew'd over what Countries and Places the intire Shadow would pass, as Doctor Halley has given us a particular Map of England for the Passage of the Total Shadow over it. But the nature of the Construction does not admit of that Projection: (Such a Thing cannot be truly represented any other way than by the Copernicus; where there is a real Globe of the Earth, capable of a Diurnal motion, during the time of the Eclipse) the impossibility of which in all Perspective Projections of the Sphere renders that design otherwise impracticable: Nor can I determine by this Construction whether the Eclipse will be Total at London or not, because the Circles of the Sun and Moon at the Southern Limit seem here exactly coincident. But if we go by a Construction according to our Calculation ye Digits Eclipsed at London will be hardly more than $11\frac{3}{5}$ and the Shadow will go full 30 Miles more Northward than in D^{r}. Halleys Map.

Engrav'd and Sold by Iohn Senex at y^{e} Globe in Salisbury Court near Fleet Street. And Will: Taylor at y^{e} Ship in Paternoster Row. Where are sold M^{r} Whistons Astronomical Lectures, his Taquet's Euclid, and y^{e} Scheme of y^{e} Solar System. Also y^{e} Newest Globes and Maps.

The Copernicus, or Universal Instrument, being now finish'd, is sold by y^{e} Author M^{r} Whiston, at his House in Cross street Hatton Garden.

Empire, the *Britains* and the *Saxons*."[50]

However, in the two broadsides published in anticipation of the event, Whiston uncharacteristically ignored political or other non-astronomical implications of the eclipse, focusing instead on providing astronomical information and promoting other commercial opportunities presented by the event.[51] The print advertised along with Halley's *Description*, Whiston's *A Calculation of the Great Eclipse of the Sun ... with its Construction for London, Rome, and Stockholme* (Figure 7), sacrificed religio-political prognostication for geometric projection. The top half of the print was dominated by a geometric construction of the path of the Moon above the surface of the Earth as seen from the centre of the Sun, based on data taken from the tables of the Astronomer Royal, John Flamsteed, "as corrected according to S^{r}. Isaac Newton's Theory of y^{e} Moon in y^{e} Astronomical Lectures".[52] Armed with a pair of compasses and following the instructions detailed in the text of the print, the careful user could determine from the projection the times and extent of the eclipse as viewed from any parallel in Europe.

Just as Whiston's print emphasized the technical aspects of eclipse prediction to a much greater degree than Halley's, so it also revealed the eclipse as an occasion for collegial competition and commercial opportunities. In his text, Whiston mentioned the competing predictions of the eclipse's parameters offered both by Halley and Flamsteed. Whiston took particular note of Halley's published map and its prediction, noting that his own calculation of the path of the eclipse, accomplished with the aid of his "Copernicus, or Universal Astronomical Instrument", moved the bounds of the path published in Halley's *Description* 30 miles to the north, added eleven minutes to Halley's predictions of the times for the beginning, middle, and end of the eclipse at London, and cautiously predicted that the Moon would only eclipse $11\frac{3}{5}$ digits of the Sun as viewed from London, thereby making it just short of total. Whiston further asserted that his calculation was superior to that of Halley's because it relied on the "Copernicus", a three-dimensional device invented specially to aid in the determination of solar and lunar eclipses, which (Whiston claimed) allowed its user to account for the diurnal motion of the Earth, a variable not incorporated in calculations based exclusively on a projection of the Earth's sphere. At the bottom of this print, Whiston noted that those who wished to reproduce his calculations could purchase a "Copernicus" from him.[53]

From both the informative and the commercial standpoints, it seems likely that this broadside was less successful than Halley's; recall that that the newspaper advertisement quoted above calls the print published in April of 1715 a "new edition" of Halley's print, suggesting that Senex may have published two editions of the map. The apparent commercial success of Halley's broadside testifies to the simplicity of its presentation of the eclipse: using the map of England, a potential observer could locate himself and easily determine whether his location would provide (according to Halley's prediction) a good view of the eclipse, or how far he might have to travel to get one. Thus Halley's print took best advantage of the medium, by providing an attractive illustration that placed the eclipse in a context

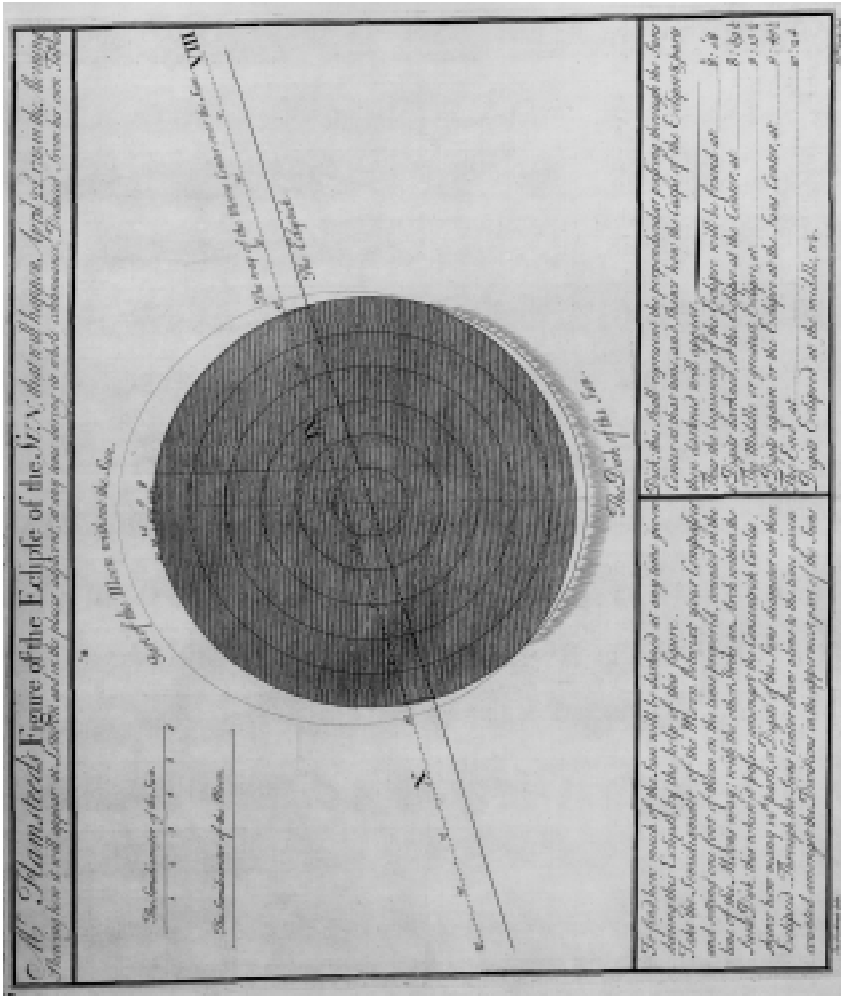

Fig. 8. Flamsteed's *Figure of the Eclipse of the Sun, that will happen April 22d 1715*. Houghton Library, Harvard University. 35 × 40 cm.

everyone could understand and relate to.

In contrast to Halley's straightforward approach, Whiston squandered the potential advantages of the broadside as a medium for astronomical instruction by providing too much technical information (the geometric projection, along with the data on which it was based and an explanation of how it was calculated), and very little information of use to the casual eclipse observer. A brief comparison of Whiston's print with a broadside that took a similar approach to illustrating the eclipse, *M^{r}. Flamsteed's Figure of the Eclipse of the Sun* (Figure 8), suggests Whiston's mistake; rather than attempting to provide a predictive projection encompassing all of Europe, along with the astronomical data and the calculation from which the projection was derived, this print's data provided just the times and illustrated the eclipse as it would appear "at London and in the places adjacent". [54] In short, by attempting to encompass too much information in his broadside, Whiston produced a product that likely appeared incomprehensible and intimidating to many.

Whiston corrected these flaws in his second effort, the one-shilling *Compleat Account of the great Eclipse of the Sun* (Figure 9), which took better advantage of the possibilities of the medium. Dated by Whiston April 22 1715 (old style), the *Compleat Account* was larger, more expensive, and more comprehensive than either of the prints advertised concurrently in the *London Gazette*. Targeting a broader audience than he had in his previous print, Whiston limited his calculation of the

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Text of Figure 8]

M^{r}. Flamsteed's *Figure of the Eclipse of the Sun*, that will happen April 22^{d} 1715, in the Morning. Shewing how it will appear at London and in the places adjacent, at any time during its whole continuance. Deduced from his own Tables.

To find how much of the Sun will be darkned at any time given during this Eclipse, by the help of this figure.

Take the Semidiameter of the Moon betwixt your Compasses and setting one foot of them on the time proposed, counted in the line of the Moons way; with the other Strike an Arch within the Suns disk: this where it passes amongst the Concentrick Circles, shews how many 12th parts, or Digits of the Suns diameter are then Eclipsed. Through the Suns Center draw a line to the time given and counted amongst the Divisions in the uppermost part of the Suns Disk; this shall represent the perpendicular passing through the Suns Center at that time, and Shews how the Cusps of the Eclipses & parts then darkned will appear.

Thus the beginning of the Eclipse will be found at	8^{h}: 08′
6 Digits darkned, or the Eclipse at the Center, at	8: $39\frac{1}{2}$
The Middle or greatest Eclipse, at	9: $13\frac{1}{2}$
6 Digits again or the Eclipse at the Suns Center, at	9: $49\frac{1}{2}$
The End at	10: 24

Digits Eclipsed at the middle, $11\frac{3}{4}$

Jos. Crosthwait delin.
M. V.^{dr} Gucht Scul.

eclipse, and the data used to accomplish it, to a section at the bottom of the print amounting to less than a quarter of its total area. Instead of highlighting the technical aspects of the eclipse, Whiston used most of the space of the *Compleat Account* to offer useful information to the novice observer. For example, in a section of the print titled "Directions for the easie Observation of the Eclipse", Whiston cautioned his readers not to look at the eclipse directly, either with the naked eye or an unshaded telescope. As alternatives to these unsafe practices, Whiston listed four possible means of effectively observing the Sun during the eclipse: by looking at the Sun through either a pin-hole aperture (not a method recommended today) or a smoked glass, or by projecting the Sun's image using either a pin-hole camera or (preferably) a telescope, the last method producing results "sufficiently exact for the purposes of even the Astronomers themselves". [55]

To assist would-be observers in preparing for the eclipse, Whiston also included directions for finding the true meridian, and a celestial map (presumably for the latitude of London) of those sections of the ecliptic and lunar orbit in which the Sun and Moon were to be located around the time of the eclipse. With the proper observational set-up, observers could determine several characteristics of the eclipse: the local times of its beginning and ending, the duration of total darkness (to the nearest second), and the change in Sun's colour and intensity. Whiston also noted that eclipse offered an opportunity to observe, among other astronomical phenomena, "the Sun's Milky Way" (the solar corona), and the planets Jupiter, Venus, and Mercury — the latter "so very rarely seen, that excepting such an unusual opportunity as this is, few here have any occasion of seeing him in their whole Lives". He expressed his hope that careful observation during the eclipse might enable observers to determine whether or not the Moon had an atmosphere, and, quite possibly, lead to the discovery of a new comet or planet very near to the Sun. In conclusion, Whiston requested that "the Curious" send the results of their observations to him, as he intended "to Publish another such a Print with an Account of the Eclipse it self as it shall really Appear, together with its Circumstances, and the Natural consequences from those Observations, for the intire satisfaction of the Inquisitive".[56]

To facilitate the observation and recording of the kind of data that would make up such a publication, it appears that Whiston contributed one more item to the collection of ephemera marking this eclipse, *The Method of the Observations to be made at the Solar Eclipse, April 22d, 1715*. Sold for 2 pence, this unsigned sheet included four parallel columns, two listing the times predicted for the course of the eclipse and the phenomena that were likely to be visible, and two providing space for the observer to note his or her own time measurements and observations. Whiston's involvement in its publication is suggested by the initial instruction, "Set each *Copernicus* to the time; and keep it right all along the Eclipse", and by the predicted times for the beginning, middle, and end of the eclipse, which correspond to those published by Whiston in his *Complete Account*. Like the latter broadside, *The Method of the Observations* also indicated that the observer should be able to view various astronomical phenomena such as the "Sun's Milky Way", as

TABLE 2. Broadside predictions of the 1715 solar eclipse, for observations from London.

	Halley[1]	Whiston I[2]	Whiston II[3]	Flamsteed[4]	Actual[5]
Begin	8:07	8:18	8:07:30	8:08	8:06
Middle	9:13	9:24	9:14	9:13:30	9:09
End	10:24	10:35	10:24:30	10:24	10:20

1. From Halley, *A Description of the Passage of the Shadow of the Moon over England* (ref. 20).
2. From Whiston, *A Calculation of the Great Eclipse of the Sun* (ref. 51).
3. From Whiston, *A Compleat Account of the great Eclipse of the Sun* (ref. 51).
4. From *Mr. Flamsteed's Figure of the Eclipse of the Sun* (ref. 54).
5. From Halley, "Observations of the late Total Eclipse of the Sun..." (ref. 14).

well as Jupiter, Venus, and Mercury.[57]

Whiston's *Compleat Account* offered a more comprehensive — and comprehensible — interpretation of the eclipse than any other broadside published in 1715. But, it also likely saved Whiston from some embarrassment. In both of his prints, Whiston had pointedly compared his predictions to those of Edmond Halley (as published in his *Description*) and the Astronomer Royal, John Flamsteed. However, though Whiston declared in his *Compleat Account* that his "former Scheme or Construction ... agrees with the present Calculation", the predicted times given for the eclipse in his *Compleat Account* differed significantly from those his *Calculation*, while they came to within one minute of the figures predicted by Halley and Flamsteed (Table 2). Ultimately, Whiston's correction proved fortunate; Halley's observations and timing of the eclipse put it to within five minutes of the final predictions offered by the three astronomers.[58]

The revised predictions offered by Whiston in the *Compleat Account* raise questions as to the fate of Whiston's "Copernicus"; though it featured prominently in the *Calculation*, no mention was made of it in the later broadside. Perhaps it was felt that the inaccuracies of the *Calculation* tainted the reputation of the device featured so prominently in the broadside; or perhaps the "Copernicus" did not sell well, and so Senex was unwilling to devote more advertising space to it.

While Whiston's efforts to publicize his predictions for the eclipse of 1715 offer insight into pedagogical strategies for the popularization of astronomy in the early eighteenth century, the account of those efforts that he recorded in his *Memoirs* suggests the tangible benefits that flowed from the production of such media. Writing of his activities around the eclipse of 1715, Whiston noted

> I myself by my lectures before, by the sale of my schemes before and after; by the generous presents of my numerous and noble Audience; who at the Recommendation of my great Friend the Lord *Stanhope*, then Secretary of State, gave me a guinea apiece ... [I] gained in all £120 by it. Which in the circumstances I then was, and have since been, destitute of all preferment, was a very seasonable and plentiful supply: and as I reckoned, maintained me and my family for a whole year together.[59]

Gifts from patrons constituted at least £25 of the £120 Whiston earned on the eclipse in 1715; profits from lecturing and the eclipse prints he produced thus summed to

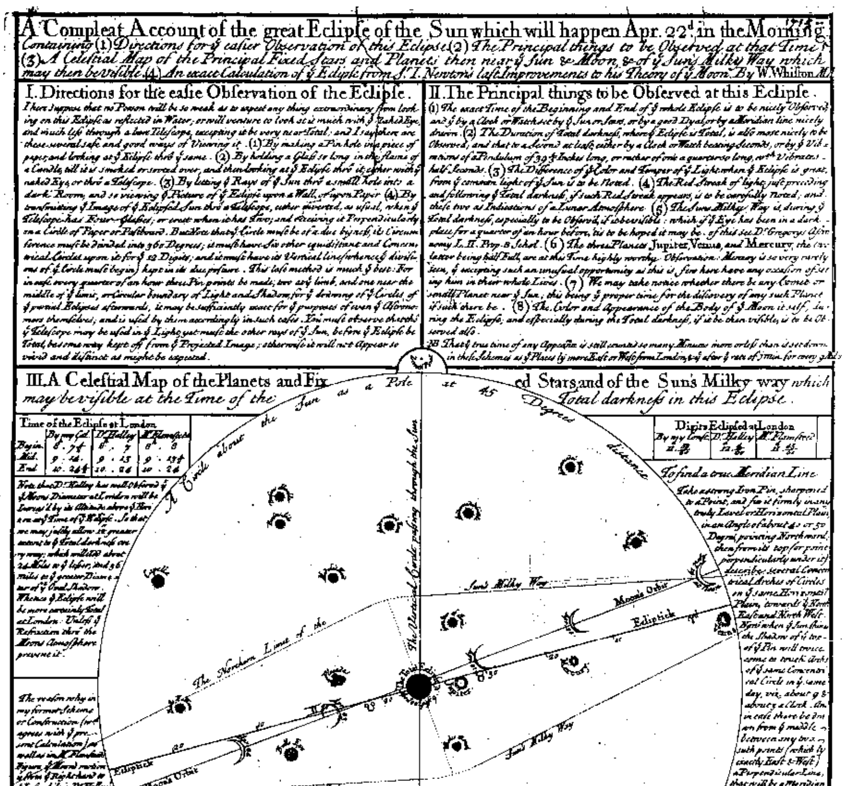

FIG. 9. Whiston's *A Compleat Account of the great Eclipse of the Sun* (1715). Science Museum Library, London. 42 × 27 cm.

Text of Figure 9]

A Compleat Account of the great Eclipse of the Sun which will happen Apr. 22d in the Morning. Containing (1) Directions for y^e easier Observation of this Eclipse. (2) The Principal things to be Observed at that Time. (3) A Celestial Map of the Principal Fixed Stars and Planets then near y^e Sun & Moon, & of y^e Sun's Milky Way which may then be visible. (4) An exact Calculation of y^e Eclipse from S^r. I. Newton's last Improvements to his Theory of y^e Moon. By *W. Whiston* MA

I. Directions for the easie Observation of the Eclipse.
I here suppose that no Person will be so weak as to expect any thing extraordinary from looking on this Eclipse reflected in Water; or will venture to look at it much with y^e Naked Eye; and much less through a bare Telescope, excepting it be very near Total; and I say there are these several safe and good ways of Viewing it. (1) By making a Pin hole in a piece of paper, and looking at y^e Eclipse thrô y^e same. (2) By holding a Glass so long in the flame of a Candle, till it is smoked or sooted over, and then looking at y^e Eclipse thrô it, either with y^e naked Eye, or thrô a Telescope. (3) By letting y^e Rays of y^e Sun thrô a small hole into a dark Room, and so viewing y^e Picture of y^e Eclipse upon a Wall, or upon Paper (4) By transmitting y^e Image of y^e Eclipsed Sun thrô a Telescope, either inverted, as usual, when y^e Telescope has Four Glasses; or erect when it has Two; and receiving it Perpendicularly on a Circle of Paper or Pastboard. But Note that y^e Circle must be of a due bigness, its Circumference must be divided into 360 Degrees; it must have Six other equidistant and Concentrical Circles upon it for y^e 12 Digits; and it must have its Vertical line (whence y^e divisions of y^e Circle must begin) kept in its due posture. This last method is much y^e best: For in case every quarter of an hour three Pin points be made; two at y^e limb, and one near the middle of y^e limit, or Circular boundary of Light and Shadow, for ye drawing of y^e Circles of y^e partial Eclipses afterwards, it may be sufficiently exact for y^e purposes of even y^e Astronomers themselves; and is used by them accordingly in such cases. You must observe that thô y^e Telescope may be used in y^e Light, yet must the other rays of y^e Sun, before y^e Eclipse be Total, be some way kept off from y^e Projected Image; otherwise it will not Appear so vivid and distinct as might be expected.

II. The Principal things to be Observed at this Eclipse.
(1) The exact Time of the Beginning and End of y^e whole Eclipse is to be nicely Observed, and y^t by a Clock or watch set by y^e Sun or Stars, or by a good Dyal, or by a Meridian line nicely drawn. (2) The Duration of Total darkness, where y^e Eclipse is Total, is also most nicely to be Observed; and that to a Second at least; either by a Clock or Watch beating Seconds, or by y^e Vibrations of a Pendulum of 39$\frac{1}{5}$ Inches long, or rather of one a quarter so long, w^{ch} Vibrates half Seconds. (3) The Difference of y^e Color and Temper of y^e Light when y^e Eclipse is great from y^e common light of y^e Sun is to be Noted. (4) The Red Streak of light, just preceding and following y^e Total darkness, if such Red Streak appears, is to be carefully Noted; and these two as Indications of a Lunar Atmosphere (5) The Suns Milky Way is, during y^e Total darkness, especially to be Observ'd, if it be visible: which if y^e Eye has been in a dark place for a quarter of an hour before, 'tis to be hoped it may be. of this see D^r. Gregorys Astronomy L. II. Prop. 8 Schol. (6) The three Planets *Jupiter*, *Venus*, and *Mercury*, the two latter being half Full, are at this Time highly worthy Observation: Mercury is so very rarely seen, y^t excepting such an unusual opportunity as this is few here have any occasion of seeing him in their whole Lives. (7) We may take notice whether there be any Comet or small Planet near y^e Sun; this being y^e proper time for the discovery of any such Planet if such there be. (8) The Color and Appearance of the Body of y^e Moon itself, during the Eclipse; and especially during the Total darkness, if it be then visible, is to be Observed also.

NB That y^e true time of any Appearance is still counted so many Minutes more or less than is set down in these Schemes as y^e Places ly more East or West from London, & y^t after y^e rate of j Min. for every 9 Miles.

III. A celestial Map of the Planets and Fixed Stars of the Sun's Milky way which may be visible at the Time of the Total darkness in this Eclipse.

Time of the Eclipse at London

	By my Cal.	D^r. Halley	M^r. Flamsteed
Begin.	8^h 7$\frac{1}{2}$′	8^h 7′	8^h 8′
Mid.	9^h 14′	9^h 13′	9^h 13$\frac{1}{2}$′
End	10^h 24$\frac{1}{2}$′	10^h 24′	10^h 24′

Text of Figure 9, continued]

Digits Eclipsed at London

By my Const.	D^{r}. Halley	M^{r}. Flamsteed
11^{d}. 59/60	12^{d}. 4/60	11d. 45/60

Note that D^{r}. Halley has well Observd yt y^{e} Moons Diameter at London will be Increas'd by its Altitude above y^{e} Horizon at y^{e} Time of y^{e} Eclipse. So that we may justly allow 12″ greater extent to y^{e} Total darkness every way; which will Add about 24 Miles to y^{e} lesser, and 36 Miles to y^{e} greater Diameter of y^{e} Oval Shadow. Whence y^{e} Eclipse will be more certainly Total at London: Unless y^{e} Refraction thro the Moon's Atmosphere prevent it.

To find a true Meridian Line
Take a strong Iron Pin, sharpened to a Point, and fix it firmly in any truly Level or Horizontal Plain, in an Angle of about 40 or 50 Degres, pointing Northward; then from its top (or point perpendicularly under it) describe several Concentrical Arches of Circles on y^{e} same Horizontal Plain, towards y^{e} North East and North West. Now when y^{e} Sun shines the Shadow of y^{e} top of y^{e} Pin will twice come to touch Archs of y^{e} same Concentrical Circle in y^{e} same day, viz. about 9 & about 3 a Clock. And in case there be drawn from y^{e} middle between any two such points (which ly exactly East & West) a Perpendicular Line, that will be a Meridian or 12 a Clock Line.

The reason why in my former Scheme or Construction (w^{ch} agrees with y^{e} present Calculation) as well as in Mr. Flamsteeds Figure y^{e} Moon's motion is from y^{e} Right hand to y^{e} Left, while in Dr. Halley's Scheme it is from y^{e} Left hand to y^{e} Right is, that y^{e} eye in the former Case is suppos'd to look up from below towards y^{e} Eclipse itself in y^{e} Heaven; and in y^{e} latter from above down towards y^{e} Shadow of y^{e} Eclipse upon the Earth.

It is worth Observing yt y^{e} French Accounts Publish'd in our Prints, do very well agree with y^{e} Present Calculation and Construction, both as to y^{e} Time and quantity of this Eclipse.

NB. This Map is a Projection of near one seventh Part of the Sphere, Describ'd at 45 Deg: distance from the Sun and Moon as a Pole, at the Middle of this Eclipse. It is made by a Tangent Line of 45 Deg. equal to the Radius of the circle, whose Plain is supposed Perpendicular to a Line from the Center of the Earth to the Center of the Sun and Moon: And that therefore if it be held up between y^{e} Eye of y^{e} Spectator (at y^{e} distance of half y^{e} Diameter of y^{e} Circle) and y^{e} Center of y^{e} Sun and Moon dureing y^{e} Total Eclipse, with its Vertical Line in y^{e} Vertical Circle, and y^{e} Center be directed to the Eclipse, every one of y^{e} Fixed Stars and Planets will be in those lines y^{t} are extended from y^{e} Eye thrô y^{e} Centers of those Fixed Stars and Planets in y^{e} Map; And so will easily be known by every Observer.

IIII. A most exact Calculation of this Eclipse according to S^{r}. Isaac Newton's last Improvements to his Theory of y^{e} Moon

[Table: "Moon's mean Motion", "Motion of the Apogee", "Motion of y^{e} Node Retr.", and Whiston's calculation of the Eclipse]

[Table: "The Sun's True Place and Anomaly" for April 22 1715]

So that the Middle of the general Eclipse in common Time will be but 42 Min 41 Seconds after 9 in y^{e} Morning; agreeing very nearly with D^{r}. Halley's Description and M^{r}. Flamsteeds latest Calculation. Note also that hence y^{e} Constant breadth of y^{e} Shadow of Total darkness will be 98 Geographical Miles; and that its length on y^{e} Oblique Horizon of England will be near 150 Miles as D^{r}. Halley's Description of this Eclipse asserts.

NB. The Author desires y^{e} Curious as soon as may be after y^{e} Eclipse is over, to communicate their Observations to him: He then intending to Publish another such a Print with an Account of the Eclipse it self as it shall really Appear, togather with its Circumstances, and y^{e} Natural consequences from those Observations, for y^{e} intire satisfaction of y^{e} Inquisitive. W.W. Apr. 2^{d}. 1715.

Engraved and sold By I. Senex at y^{e} Globe in Salisbury Court near Fleetstreet. And by y^{e} Author in Cross Street Hatton Garden. also by Will. Taylor at the Ship in Paternoster.

perhaps £95 — an amount just less than the £100 stipend attached to the Lucasian chair.[60] Most of that sum was probably earned through lecturing — a single night's lecture on a specific scientific topic probably cost around five shillings.[61] But, Whiston's mention of his two prints suggests that the sale of these, along with whatever he earned through the sale of its copyright to Senex, contributed a significant sum to this year's income.[62] In short, Whiston's comments make clear that the production and sale of broadsides such as those described here provided an important means of generating income for their producers, both as commodities in and of themselves, and from money made by other businesses and astronomical products advertised by them.

Like Halley, Whiston reawakened his business interest in eclipses in anticipation of the eclipse of 1724, publishing *The Transit of the Total Shadow of the Moon over Europe* (Figure 10). Perhaps the most striking aspect of this broadside is its similarity to Halley's *Description of the Passage of the Shadow of the Moon over Europe* (Figure 5); both depicted the course of the shadow of the eclipse superimposed over a map of Europe, and, not only were the prints the same size, but their maps of Europe were drawn to nearly the same scale. Both also mentioned the utility of eclipses for determining the longitude of those places where the eclipse was observed; and both solicited observations from (in Whiston's words) "inquisitive Observers". Whiston's provides more information about the eclipse than Halley's, including the times of the eclipse for locations from Galway to Milan, as well as a prediction of those areas that would be covered by the shadow of totality. And, as noted above, Whiston's predictions for the path of the eclipse and its times also vary from those of Halley.

Whatever their similarities and differences, Halley's broadside enjoyed two big advantages in the broadside market: the name of its author, who, as Astronomer Royal, had reached the top of his profession, and the marketing and distribution network to which Senex, as a bookseller, had access. In contrast, although Whiston's broadside advertised those of his works published by Senex, it was almost certainly not published by Senex, but by Whiston himself (who, as publisher, may have paid Senex or one of his workmen to engrave it). The reason for Senex's failure to publish Whiston's 1724 print is simple. In 1715, Whiston had produced broadsides that complemented and extended the illustration of the eclipse offered in Halley's *Description of the Passage of the Shadow of the Moon*; Senex could therefore reasonably expect that anybody who purchased one might purchase another. In 1724, Whiston's decision to produce an eclipse map virtually guaranteed that Senex would not publish it; indeed, publishing Whiston's broadside would have represented a very poor business decision on the part of Senex, since its resemblance to Halley's broadside would likely have undercut sales of the latter.

Though Whiston's adoption of the map format for his 1724 eclipse print likely meant that he had to sacrifice his access to Senex's book-trade distribution network, it made some commercial sense from Whiston's point of view, since he still had copies of his 1715 broadsides for sale; taken together, the three broadsides he

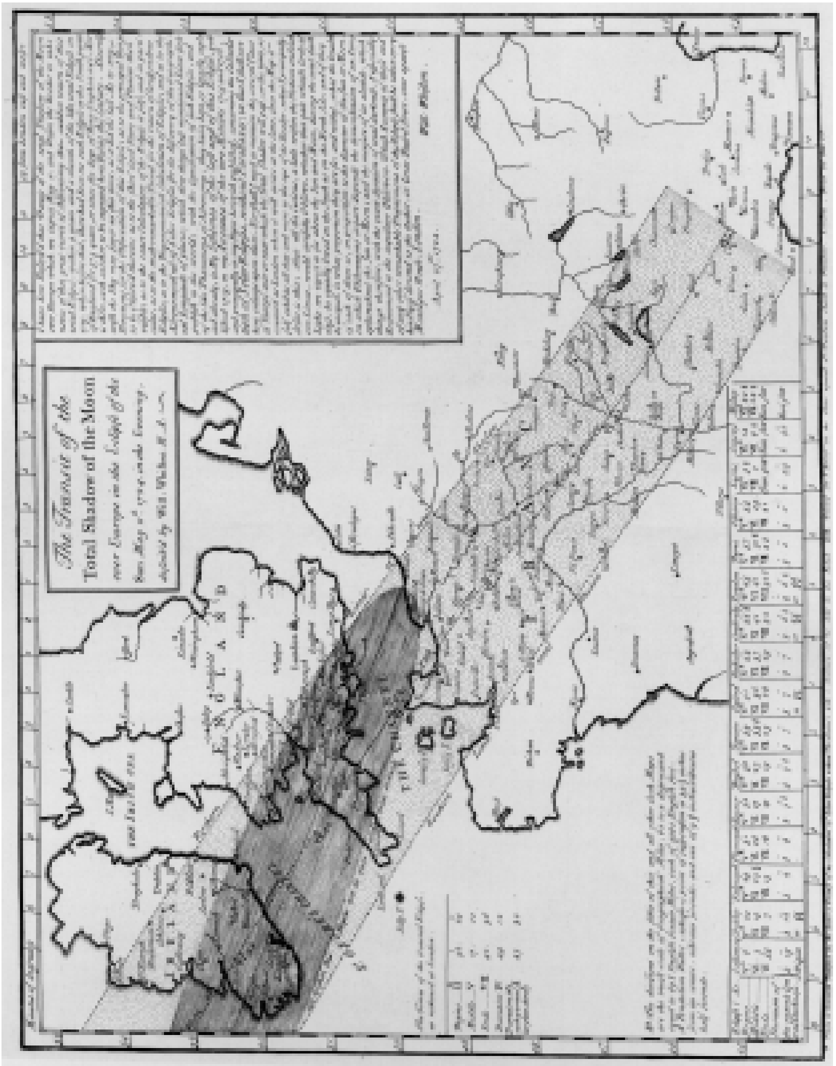

FIG. 10. Whiston’s prediction of the 1724 eclipse of the Sun. Houghton Library, Harvard University. 37 × 47 cm.

Text of Figure 10]

The Transit of the *Total Shadow of the Moon* over Europe in the Eclipse of the *Sun* May 11th 1724 in the Evening, describ'd by Will: Whiston *M.A.*

I have here Describ'd that Transit of the total Shadow of the Moon over Europe which we expect May 11 and Desire the Reader to take notice of that great secret of Astronomy the sudden return of this total Eclipse, within 9 years and a month of the like total Eclipse in 1715, when before that, there had been no such Eclipse in the South parts of England for 575 years, or since the days of King Stephen 1140. Nor is there such another to be expected here During this Century. I heartily wish the Sky may favor us this time, as it did the last. As to any Directions for the Observation of this eclipse; as to the principal things to be Observ'd therein; as to the Chief fixed Stars and Planets then visible; as to the exact Calculation of the Eclipse it self, and in particular, as to the most remarkable Period for the return of Corespondent Eclipses; as to the Trigonometrical Calculation of Eclipses; and as to the Astronomical use of Solar Eclipses for the discovery of the Geographical Longitude of places; which three things last mentioned I now first publish to the world; with the signification of such Eclipses, and of the like Phaenomena of Astronomy, they have been so largely explaind already, in My Schemes of the last and of this Eclipse, published 1715. in my Accounts of the two Meteors 1715 and 1716. and principally in my Paper herewith published, concerning the Calculation of Solar Eclipses, without Parallaxes; &c that I shall not here enlarge upon them. Nor shall I need to mention the several Places of Europe over or near which the Total Shadow will pass; or the times, as counted at London when it will arrive at the same; since the Map itself exhibits all that and more to the eye of the Reader. what I principally desire is this; that all the Curious, a little within the Northern or Southern Limits, would carefully Observe, whether that pale whitish Circle of Light we expect to see about the Sun and Moon, during the total darkness, be equally broad on the South as on the North side; and if they be unequal, in what proportion they are so: and withal, what the breadth of each of them is, in proportion to the diameter of the Sun or Moon. on which Observations in part depends the demonstration of an Atmosphere about the Sun or Moon; and the measure of its altitude. which things therefore, with the exact duration of total darkness, I especially Recommend to the inquisitive Observers. Whose Accounts of those and of any other remarkable Phaenomena of this Eclipse shall be taken very kindly if directed to the Author, in Great Russel Street, over against Montague House, London.

Will: Whiston
April 27th, 1724

The Times of the General Eclipse as reckoned at London

	h	′	″
Begins	II	52	24
Middle	V	17	00
Ends	VII	41	36
Duration	IV	49	12
Duration in each particular place about	I	47	30

NB. The divisions on the sides of this and all other such Maps are the truest scale of Geographical Miles, 60 to a degree; and equal to 69½ English Statute Miles, each of 5280 English feet. A Pendulum Bullet whose point of suspension is 39⅕ inches from its center, vibrates seconds: and one of 9- inches vibrates half seconds.

Table along bottom:
[Beginning, Middle, End, Duration, and Digits eclipsed for the following locations:
Galloway, Dublin, Falmouth, Plymouth, Exeter, Bristol, Sarum, Oxford, Chichester, Cambridge, London, Paris, Orleans, Lyons, Geneva, and Milan]

Data for London (from table)

Begin	V^h	45′
Middle	VI^h	41′

produced for the 1715 and 1724 events provided a quite comprehensive overview of the astronomy of eclipses. Purchasers who wanted even more information about eclipses could turn to another of Whiston's works, a short text published that year by Senex and Taylor, *The calculations of solar eclipses without parallaxes,* which, as the subtitle noted, used the 1724 eclipse to illustrate the general theory outlined in the work:

> As to any Directions for the Observation of this eclipse; as to the principal things to be Observ'd therein; as to the Chief fixed Stars and Planets then visible; as to the exact Calculation of the Eclipse it self, and in particular, as to the Trigonometrical Calculation of Eclipses; and as to the Astronomical use of Solar Eclipses for the discovery of the Geographical Longitude of places; which three things last mentioned I now first publish to the world; with the signification of such Eclipses, and of the like Phaenomena of Astronomy, they have been so largely explaind already, in My Schemes of the last and of this Eclipse, published 1715 in my Accounts of the two Meteors 1715 and 1716 and principally in my Paper herewith published, concerning the Calculation of Solar Eclipses, without Parallaxes; &c that I shall not here enlarge upon them.[63]

Whiston's *Transit* demonstrates that he had learned an important lesson about presenting astronomical events to the public from the 1715 eclipse: the simpler, the better. His use of a map to depict his prediction of the 1724 event established what was virtually a standard format for the illustration of solar eclipses to the English public. In 1737, 1748, and 1764, astronomers and entrepreneurs produced various maps depicting the progress of the Moon's shadow over the globe, sometimes in broadside form, and sometimes supplemented by other information thought to be of use to the public. Indeed, in 1764, so many eclipse maps were on the market — each with a different prediction — that one commentator likened the competition between them and their producers to an event quite familiar to the English public: a horse race.[64]

The astronomical broadsides produced by Whiston, Halley, their contemporaries and their successors, constituted an important medium for the consumption of sanctioned scientific knowledge. Comparatively inexpensive, easily transportable, and well-illustrated, these prints could enlighten audiences displaced by income,

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Text of Figure 10, continued]

End	VII^{h}	$32\frac{1}{2}'$
Duration of the nearest central darkness	$3'$	$6\frac{1}{2}''$
Digits	11 48/60	

NB There is herewith Published by the Author a Treatise of the Calculation of Solar Eclipses without Parallaxes: with a Specimen of the same in this Eclipse both Printed for I. Senex at the Globe against St. Dunstans Church in Fleetstreet London. Price of this 1s.

distance, or level of literacy from those who gained their astronomical knowledge from lectures or books.[65] By making eclipses commercially and intellectually accessible, they also helped to establish the cultural legitimacy of the new science among its ever-expanding public. As they mobilized public participation in the observation of an event like an eclipse, and even declared such participation of importance in refining eclipse theory, these prints emphasized the public, open character of the new science, increasing popular awareness of, and interest in, astronomy and the astronomical community.

ACKNOWLEDGEMENTS

It is a pleasure, as always, to thank John Heilbron for his advice and insight. Conversations with Frances Willmoth, Bill Burns, Tim Alborn, Jim Evans, and Liba Taub helped to clarify various points in this work, for which I am most grateful. Thanks are also due to Owen Gingerich, for drawing my attention to the Luttrell broadsides at the Houghton. A version of this paper was given at the 1997 History of Science Society meeting in San Diego, where the comments and criticisms of fellow panellists and members of the audience proved very helpful. Finally, I wish to thank the Adler Planetarium for providing the funds that enabled me to travel to Chicago to examine and make use of their history of astronomy collection, which includes many of the broadsides discussed here.

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1. On public science in eighteenth-century England, see Larry Stewart, *The rise of public science: Rhetoric, technology, and natural philosophy in Newtonian Britain, 1660–1750* (Cambridge, 1992), and Jan Golinski, *Science as public culture: Chemistry and enlightenment in Britain, 1760–1820* (Cambridge, 1992).
2. On public lectures, private consumption, and science in eighteenth-century England, see (among other works) Stewart, *op. cit.* (ref 1), esp. Part II; Golinski, *op. cit.* (ref. 1), esp. chap. 2; Alan Q. Morton and Jane A. Wess, *Public & private science: The King George III Collection* (Oxford, 1993); *The British journal for the history of science*, xxviii/1 (1995), which is devoted to scientific lecturing; Simon Schaffer, “The consuming flame: Electrical showmen and Tory mystics in the world of goods”, in John Brewer and Roy Porter (eds), *Consumption and the world of goods* (London, 1993), 489–526; A. Q. Morton, “Lectures on natural philosophy in London: 1750–1765: S. C. T. Demainbray (1710–1782) and the ‘Inattention’ of his countrymen”, *The British journal for the history of science*, xxiii (1990), 411–34; Simon Schaffer, “Natural philosophy and public spectacle in the eighteenth century”, *History of science*, xxi (1983), 1–43; Roy Porter, “Science, provincial culture, and public opinion in Enlightenment England”, *British journal for eighteenth-century studies*, iii (1980), 20–46; J. L. Heilbron, *Electricity in the 17th & 18th centuries* (Berkeley, 1979); Patricia Fara, *Sympathetic attractions: Magnetic practices, beliefs, and symbolism in eighteenth-century England* (Princeton, 1996); Alice N. Walters, “Conversation pieces: Science and politeness in eighteenth-century England”, *History of science*, xxxv (1997), 121–54; James A. Secord, “Newton in the nursery: Tom Telescope and the philosophy of tops and balls, 1761–1838”, *History of science*, xxiii (1985), 127–51; Roy Porter, Simon Schaffer, Jim Bennett, and Olivia Brown, *Science and profit in eighteenth-*

century London (Cambridge, 1985); John R. Millburn, *Benjamin Martin: Author, instrument maker, and 'country showman'* (Leyden, 1976); and *idem, Wheelwright of the heavens: The life and work of James Ferguson, FRS* (London, 1988). The cultural context within which science was commercialized is illuminated in John Brewer, *The pleasures of the imagination: English culture in the eighteenth century* (New York, 1997).

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4. On astrology in late seventeenth- and early eighteenth-century England, see Patrick Curry, *Prophecy and power* (Princeton, 1989); Bernard Capp, *English almanacs, 1500–1800: Astrology and the popular press* (Ithaca, 1979); Keith Thomas, *Religion and the decline of magic* (New York, 1971); and the essays in Patrick Curry (ed.), *Astrology, science, and society: Historical essays* (Woodbridge, Suffolk, 1987). On the astronomy of comets, and their interpretation, see Sara Schechner Genuth, *Comets, popular culture, and the birth of modern cosmology* (Princeton, 1997). On prodigies and their interpretation in the early eighteenth century, see William E. Burns, "An age of wonders: Prodigies in Restoration culture", unpublished typescript, esp. chap. 5. The challenges presented to natural philosophers by a similarly unusual event — the aurora — are detailed in Patricia Fara, "Lord Derwentwater's Lights: Prediction and the aurora polaris", *Journal for the history of astronomy*, xxvii (1996), 239–58.
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7. Examples of eighteenth-century astronomical broadsides, including those illustrated here, may be found in the following collections: The Oxford Museum of the History of Science (OMHS); the Whipple Museum of the History of Science, Cambridge (WMHS); the Prints Collection of the Science Museum Library, London (SML); the Map Collection of the British Library; the archives of the Royal Astronomical Society, London (RAS); the History of Astronomy Collection of The Adler Planetarium, Chicago; and the Houghton Library at Harvard University (Harvard). The latter collection is dominated by broadsides acquired by Narcissus Luttrell (1657–1732), a collector of ephemera, who conveniently noted on his broadsides both the date he purchased an item and its price.
8. On the value of curiosity and curiosities in the eighteenth century, see Barbara M. Benedict, "The 'curious attitude' in eighteenth-century Britain: Observing and owning", *Eighteenth-century life*, xiv (1990), 59–98. Benedict particularly notes that "curiosity" signified, among other things, scientific learning and scientific collecting: see esp. pp. 59–60, 78–82.
9. In 1680, the Royal Society entertained a proposal to publish "philosophical gazettes", costing no more than 2d, that would have "contrasted with the rather bulkier and more expensive format of the *Philosophical transactions*". However, the idea was abandoned. See Michael Hunter and Paul B. Wood, "Towards Solomon's House: Rival strategies for reforming the early Royal Society", *History of science*, xxiv (1986), 49–108, esp. p. 59 (quote).
10. On Senex, see E. G. R. Taylor, *Mathematical practitioners of Hanoverian England, 1714–1840*

(Cambridge, 1966), 143; Sarah Tyacke, *London map-sellers, 1660–1720* (Tring, Hertfordshire, 1978), 142; and R. V. Wallis and P. J. Wallis, *Biobibliography of British mathematicians, Part II* (Newcastle upon Tyne, 1986), 21. Senex's role as a scientific entrepreneur is illuminated in Stewart, *op. cit.* (ref. 1), esp. pp. 95, 147, 173, 187, 190. The scientific and popular role of one of Senex's prints — William Whiston's *Transits of Venus and Mercury over the Sun* (1723) — is discussed in Harry Woolf, *The transits of Venus* (Princeton, 1959), 28–29.

11. The standard work on Martin is Millburn, *Martin* (ref. 2), which together with two subsequent works by Millburn, *Benjamin Martin: Supplement* (London, 1986) and *Retailer of the sciences: Benjamin Martin's scientific instrument catalogues, 1756–1782* (London, 1986), provides a detailed portrait of this important figure in the dissemination and commercialization of science in eighteenth-century Britain.
12. This survey is based on a list of maps and prints included in Millburn, *Martin* (ref. 2), 208. Millburn lists nine prints, of which all but one, *A map of 20 miles round London*, are certainly astronomical. I have examined copies of six of these prints.
13. Aside from the lists of the prints published by Senex and Martin cited above, no comprehensive catalogue of eighteenth-century astronomical broadsides has been published. Since they present particular difficulties for the bibliographer, they are often hard to find; see, for example, the comments of Marjorie Hope Nicolson and G. S. Rousseau concerning their attempt to trace William Whiston's *Scheme of the solar system* in *"This long disease my life": Alexander Pope and the sciences* (Princeton, 1968), 147–8. More recently, the difficulties of locating often uncatalogued prints have been made evident by the Wallis's very useful *Biobibliography of British mathematics* (ref. 10), which includes those of Leadbetter (p. 85), Smith (p. 224), Witchell (p. 269), and Betts (p. 304), and some of Martin's (pp. 212–16), but which has missed several prints, often only initialled or anonymous. For insight into the challenges of locating and cataloguing such material, see R. C. Alston, "The eighteenth-century non-book: Observations on printed ephemera", in Giles Barber and Bernhard Fabian (eds), *Buch und Buchhandel in Europa im achtzehnten Jahrhundert* (Hamburg, 1981), 343–60.
14. Edmond Halley, "Observations of the late Total Eclipse of the Sun on the 22d of April last past...", *Philosophical transactions*, xxix (1714–16), 245–62, p. 261.
15. These placements for the paths of totality are based on Benjamin Martin's map, *The passage of the dark shadow of the Moon over England & other parts of Europe in the five great solar eclipses of the century* (OMHS). Almost certainly this is the map cited in Millburn, *Martin* (ref. 2), 208, as *An accurate map of 460 miles round London*, which was advertised in 1758.
16. On Harris's *Astronomical dialogues*, see Walters, *op. cit.* (ref. 2), 133.
17. On Moore's work, see Frances Willmoth, *Sir Jonas Moore: Practical mathematics and Restoration science* (Woodbridge, Suffolk, 1993), 195–207.
18. The first advertisement appeared in the *London Gazette* on 8–12 March; both advertisements are quoted in Tyacke, *op. cit.* (ref. 10), 103.
19. William Whiston, *Astronomical lectures, read in the publick schools at Cambridge* (London, 1715). Maureen Farrell, *William Whiston* (New York, 1981), 191–8, outlines the contents of the work, which was based on lectures originally given at Cambridge University between 1701 and 1703, and which was published in Latin in 1707.
20. Edmond Halley, *A Description of the Passage of the Shadow of the Moon over England, In the Total Eclipse of the SUN, on the 22d Day of April 1715 in the Morning*, Harvard. Luttrell's copy is dated 10 April, but it was likely published in March. On advertising in the scientific instrument and book trades, M. A. Crawforth, "Evidence from trade cards for the scientific instrument industry", *Annals of science*, xlii (1985), 453–554; Alice Walters, "Tools of enlightenment: The material culture of science in eighteenth-century England", Ph.D.

dissertation, University of California Berkeley, 1992, chap. 3.

21. Halley, *op. cit.* (ref. 20). Copies of this print are at the RAS, WMHS, and Harvard; Harvard's copy lists the price (in ms). The map is reproduced and discussed in Gingerich, *op. cit.* (ref. 6), 324; Armtiage, *op. cit.* (ref. 6), frontispiece, 6–9; Norman J. W. Thrower, "Edmond Halley and thematic geo-cartography", in Thrower (ed.), *The compleat plattmaker* (Berkeley, 1978), 195–228, pp. 225–7; Rodney W. Shirley, *Printed maps of the British Isles, 1650–1750* (London, 1988), 126–7; and Allan Chapman, "Edmond Halley's use of historical evidence in the advancement of science", *Notes and records of the Royal Society of London*, xlviii (1994), 167–91.
22. Nicholas Rogers, "Popular protest in early Hanoverian London", *Past and present*, no. 79 (1978), 70–100, esp. pp. 71–73; Stewart, *op. cit.* (ref. 1), 134.
23. Halley, *op. cit.* (ref. 20). See also Chapman, *op. cit.* (ref. 21), 183.
24. W. W., *The eclipse. A poem, in commemoration of the* Total eclipse of the Sun, *April 22, 1715* (London, 1715), 8. On other interpretations of the 1715 eclipse, see Burns, *op. cit.* (ref. 4), and Curry, *op. cit.* (ref. 4), 119–20; on the importance of such events in popular astrology, Curry, *ibid*., 97. On similar astrological interpretations of the solar eclipse of 1652 (called "Black Monday" by contemporaries), see Thomas, *op. cit.* (ref. 4), 299–300; and William E. Burns, "'The terriblest eclipse that hath been seen in our days:' Black Monday and the debate on astrology during the interregnum", in Margaret J. Osler (ed.), *The canonical imperative: Rethinking the Scientific Revolution*, forthcoming. For a different perspective on the motivations of "élite writers" to "dismiss ... interpretations of providential intervention as superstition", see Fara, *op. cit.* (ref. 4), 242.
25. *Speculum mundi: or, An exact account of the great and formidable eclipse of the Sun, which will be visible, total, and central, in England, May 11, 1724.* (London, 1723), 20.
26. Halley, *op. cit.* (ref. 20).
27. Halley, *op. cit.* (ref. 14), 245. See also Colin A. Ronan, *Edmond Halley: Genius in eclipse* (Garden City, N.Y., 1969), 196–7.
28. Halley took a similar approach to the aurorae of 1716, though without using the broadside as a publication medium; Fara, *op. cit.* (ref. 4), 240–6.
29. Lorna Weatherill, *Consumer behaviour and material culture in Britain, 1660–1760* (London, 1988), esp. pp. 3–4, 26–27, 88, 168, 180. See also Morton and Wess, *op. cit.* (ref. 2), 47–48.
30. Halley, *op. cit.* (ref. 14), 254. John Flamsteed similarly bemoaned the poor equipment available, to a correspondent in Northamptonshire. In a letter to Dr Hill of Peterborough, dated 28 April 1715, and sent to thank him for the eclipse data he had sent to the Royal Observatory, Flamsteed wrote, "I could wish you have been furnisht with a good Pendulum clock for observeing the times more exactly and better instruments then a sun diall...". Flamsteed Correspondence, Cambridge University Library (RGO 1/36, f. 88–89). I am most grateful to Frances Willmoth, editor of Flamsteed's correspondence, for cheerfully deciphering his handwriting and sending me a copy of this letter.
31. Halley, *op. cit.* (ref. 14), 261–2; 255. See also Chapman, *op. cit.* (ref. 21), 185.
32. Edmond Halley, *A Description of the Passage of the Shadow of the Moon over England as it was Observed in the late Total Eclipse of the SUN April 22d 1715*, Harvard; also reproduced in Gingerich, *op. cit.* (ref. 6), 325; another copy is illustrated in Armitage, *op. cit.* (ref. 6), 11. The print is dated in ms. 1 September 1715.
33. Edmond Halley, *A Description of the Passage of the Shadow of the Moon over England In the Total Eclipse of the Sun on the 11th day of May 1724 in the Evening. Togather with the Passage of the Shadow as it was Observed in the last Total Eclipse of 1715*, Harvard. The print also makes note of Senex's new business address, "in Salisbury Court near Fleetstreet". It is dated in ms.

5 November 1723. See also Armitage, *op. cit.* (ref. 6), 23.

34. Edmond Halley, *A Description of the passage of the Shadow of the Moon over Europe, as it may be expected May 11th 1724 in the Evening*, WMHS and Harvard.
35. Gingerich, *op. cit.* (ref. 6), 324.
36. Gingerich, *op. cit*. (ref. 6), 324 (quote). A modern calculation of the path of the 1724 eclipse shows that its limits were in fact located "about midway" between those established by Halley and Whiston: *ibid*, 325.
37. Richard S. Westfall, *Never at rest* (Cambridge, 1980), 649–53. Schechner Genuth comments on religion and its impact on the relationship between Halley and Whiston, *op. cit.* (ref. 4), 192–3.
38. Stewart, *op. cit.* (ref. 1), 77–97.
39. Schechner Genuth, *op. cit.* (ref. 4), 173. On Halley's moderately-Tory politics, see Burns, *op. cit.* (ref. 4); and Margaret C. Jacob, *Scientific culture and the making of the industrial West* (New York, 1997), 69–70.
40. William Whiston, *Memoirs*, i (London, 1749), 222. The print is discussed in Farrell, *op. cit.* (ref. 19), 230–2, while its impact on Pope is noted in Nicolson and Rousseau, *op. cit.* (ref. 13), 147–8.
41. The first notes that Senex is "now Engraving and will speedily Publish a most correct Pair of Globes of about 30 Inches Dter. at a moderate price & for which none are desir'd to advance yr money beforehand"; the second edition reads "(Senex) has just finished in a most Elegant manner a pair of 28 Inches diamr. fitt to adorn Publick Librarys and the Library's of the most curious". It is very difficult to determine when these globes became available; they were still being advertised as "now Engraving" *c*. 1714, and were advertised as "now finish'd" in 1729. Copies of both of these prints are in the OMHS.
42. Copies of both the Bowles and Sayer edition of Whiston's *Scheme* and the West edition of *The Newtonian System* are in the Houghton Library at Harvard.
43. On the economics of copper-plate engraving in the globe industry, D. J. Bryden, "Cartography by subscription: An unsuccessful 18th century project to issue globes", *Revista da Universidade de Coimbra*, xxvii (1979), 281–91, esp. pp. 290–1; and Peter van der Krogt, "Seventeenth century Dutch globes: Navigational instruments?", *Der Globusfreund*, nos. 38/39 (1990), 67–76, esp. pp. 70–71.
44. On Bowles and Sayer, see Ian Maxted, *The London book trades 1775–1800: A preliminary checklist* (Folkestone, 1977), 26 and 199, resp. A good discussion of the print trade can be found in Brewer, *op. cit.* (ref. 2), esp. chap. 11.
45. These lectures, and responses to them, are discussed in Nicolson and Rousseau, *op. cit.* (ref. 13), 138–66; and in G. S. Rousseau, "'Wicked Whiston' and the Scriblerians: Another Ancients–Modern controversy", *Studies in eighteenth-century culture*, xvii (1987), 22–37. See also John Loftis, "Richard Steele's Censorium", *Huntington Library quarterly*, xiv (1950), 59–60.
46. William Whiston, *A Scheme of the Solar System with the Orbits of the Planets and Comets Belonging thereto.*
47. Schechner Genuth, *op. cit.* (ref. 4), 162–8, 189–95; Nicolson and Rousseau, *op. cit.* (ref. 13), 139–40, 173–4; Rousseau, *op. cit.* (ref. 45), 21–28.
48. Rousseau, *op. cit.* (ref. 45), 28–29 (quote). In 1736, Whiston linked an increase in the incidence of meteors and northern lights seen since 1714 to the Hanoverian succession; Stewart, *op. cit.* (ref. 1), 71; Fara, *op. cit.* (ref. 4), 242–4. For the natural philosophical context of these kinds of interpretations, see Simon Schaffer, "Newton's comets and the transformation of astrology", in Curry (ed.), *op. cit.* (ref. 4), 219–44. For the persistence of "high astrology" in the early eighteenth century, and Whiston's role in it, see Curry, *op. cit.* (ref. 4), chap. 6, esp. pp. 146–8.
49. James E. Force, *William Whiston, honest Newtonian* (Cambridge, 1985), 190, n. 74; Burns, *op. cit.*

(ref. 4); on the 1715 eclipse specifically, Nicolson and Rousseau, *op. cit.* (ref. 13), 156–61; Rousseau, *op. cit.* (ref. 45), 28.

50. William Whiston, *op. cit*. (ref. 40), 240. The passage continues: "As I look upon the numerous and remarkable Eclipses of the Astronomical Year 1736, to be the like divine Signals of the End of all Shadow of Persecution there." For another comparison of Halley's and Whiston's disparate approaches to the interpretation of natural events, see Rousseau, *op. cit.* (ref. 45), esp. p. 17.
51. William Whiston, *A Calculation of the Great Eclipse of the Sun, April 22 1715 in the Morning, from Mr. Flamsteed's Tables, as corrected according to Sir Isaac Newton's Theory of the Moon in the Astronomical Lectures, with its Construction for London, Rome, and Stockholme,* WMHS, Harvard (which lists the price in ms.); and *A Compleat Account of the great Eclipse of the Sun which will happen April 22 in the Morning,* SML, item 1986–358.
52. Whiston, *Calculation* (ref. 51). Though the eclipse occurred just prior to the resolution of the controversy over the unauthorized publication of Flamsteed's *Historia coelestis* (for which Newton and Halley were chiefly responsible), the acrimony does not seem to have tainted this literature. For an account of the dispute, see Westfall, *op. cit.* (ref. 32), 686–96.
53. Whiston described this instrument in a pamphlet published the same year: William Whiston, *The Copernicus Explain'd: or a Brief Account of the Nature and Use of an Universal Astronomical Instrument...* (London, 1715). According to this pamphlet, the instrument was composed of a nine-inch terrestrial globe mounted in several nested rings, to account for the motions of the Earth, Moon, and planets. It was made by Senex, and sold by him and Whiston for six guineas; Farrell, *op. cit.* (ref. 19), 214–17; Nicolson and Rousseau, *op. cit.* (ref. 13), 158–60; Whiston, *op. cit.* (ref. 40), 181–2, 241.
54. [John Flamsteed], *Figure of the Eclipse of the Sun, that will happen April 22 1715 in the Morning. Shewing how it will appear at London and in the places adjacent, at any time during its whole continuance. Deduced from his own Tables*, Harvard. The print sold for sixpence. As it was produced by Flamsteed's assistant, Joseph Crosthwait, and Gerard Van de Gucht, an engraver who later worked on the maps for Flamsteed's *Atlas coelestis*, the print was probably published with Flamsteed's knowledge and permission, though perhaps not at his instigation; Frances Willmoth, personal correspondence. See also Armitage, *op. cit*. (ref. 6), 13.
55. Whiston, *Compleat Account* (ref. 51).
56. Whiston, *Compleat Account* (ref. 51). A letter to Whiston from Richard Allin of Sidney Sussex College, Cambridge, providing an account of the eclipse, is quoted in Farrell, *op. cit.* (ref. 19), 219–20; although Allin does not specifically mention either of Whiston's prints, he does record that those with whom he observed the eclipse were able to see Jupiter, Venus, and Mercury, and one or two stars, but not the "sun's Milky Way" or any evidence of a lunar atmosphere. Whiston noted in his *Memoirs* that he subsequently published an "Account of that [the eclipse of 1715] and of the next total Eclipse of the Sun, May 11, 1724"; Whiston, *op. cit.* (ref. 40), 238–9. I have not located such a print, but, as should be evident by now, that does not mean it was not published or has not survived.
57. *The Method of the Observations to be made at the Solar Eclipse, April 22d, 1715*, Harvard (price noted in ms.).
58. Since Whiston does not address the differences in his two published predictions, it is difficult to say why his first prediction differed so much from his second or from those of Halley and Flamsteed. However, the astronomical data provided in the *Calculation* differ from that in the *Compleat Account*, which suggests that the new prediction in the latter was based on updated data. See also Armitage, *op. cit*. (ref. 6), 12; and Whiston, *op. cit.* (ref. 40), 239.
59. Whiston, *op. cit.* (ref. 40), 239; also quoted in Farrell, *op. cit.* (ref. 19), 213.
60. Westfall, *op. cit.* (ref. 32), 206; Heilbron, *op. cit.* (ref. 2), 153.

61. This estimate is based on the common-sense assumption that Whiston would have charged more for a single lecture than for a lecture course; at the time of the 1715 eclipse, Whiston and his partner Francis Hauksbee charged 3 guineas for a course of 28 lectures, or about 2 shillings 3 pence per lecture. It appears that 5 shillings was a standard charge for a single-evening event at the Censorium, a theatre run by one of Whiston's patrons, Richard Steele, which also hosted other lectures by Whiston. Loftis, *op. cit.* (ref. 45); Farrell, *op. cit.* (ref. 19), 207–14.
62. The fact that Senex's stock at his death included copies of Whiston's two 1715 prints strongly suggests that he published it, and acted as its wholesale distributor. As the engraver of the two prints, he had some stake in the original copyright, so he probably paid Whiston for his share of this copyright. A good place to start for an introduction to the complexities of early-eighteenth century copyrights is John Feather, *A history of British publishing* (London, 1988), esp. chap. 6.
63. William Whiston, *The Transit of the Total Shadow of the Moon over Europe in the Eclipse of the Sun May 11th 1724 in the Evening, described by Will. Whiston M.A.*, Harvard. The print is dated by Whiston 27 April 1724. See also Armitage, *op. cit*. (ref. 6), 13–14; and William Whiston, *The calculation of solar eclipses without parallaxes. With a specimen of the same in the total eclipse of the Sun, May 11, 1724* (London, 1724), which is discussed in Farrell, *op. cit.* (ref. 19), 225–6. The work sold for 1 shilling 6 pence. Whiston later complained "This Book has so many Mistakes, that 'till they are corrected, I do not desire to have it spread abroad any longer". Whiston, *op. cit.* (ref. 40), 315. On the other publications he lists, see Fara, *op. cit*. (ref. 4), 251; and Farrell, *op. cit.* (ref. 19), 160–1, 220–3.
64. *Eclipse races, (Addressed to the LADIES): being an impartial account of the celestial coursers and their riders...* (London, 1764). It was almost certainly written by Robert Heath, who also produced a more conventional pamphlet — with map — detailing the eclipse, *A General and Particular Account of the Annular Eclipse of the Sun…* (London, 1764). Copies of both are in the OMHS. Heath's competitors included George Witchell, Benjamin Martin, and Joseph Betts, among others.
65. Walters, *op. cit.* (ref. 2), 146.

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TOWARDS A HISTORY OF GEOGRAPHY IN THE PUBLIC SPHERE

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In his *Father and son*, Edmund Gosse comments on the way he was taught geography — at home and by his father:

> My Father ... had a scheme for rationalizing geography, which I think was admirable. I was to climb upon a chair, while, standing at my side, with a pencil and a sheet of paper, he was to draw a chart of the markings on the carpet. Then, when I understood the system, another chart on a smaller scale of the furniture in the room, then of a floor of the house, then of the back-garden, then of a section of the street. The result of this was that geography came to me of itself, as a perfectly natural miniature arrangement of objects, and to this day has always been the science which gives me least difficulty.[1]

This paper discusses geography in the public sphere. Yet, as I hope to suggest in what follows, the notions of 'public sphere' and 'private space' should not uncritically be considered separate categories in understanding the sites and spaces in which knowledge was made popular and public during the 'long eighteenth century'. What follows has several aims. The first is to make connections between recent work on the spaces and situated nature of knowledge within the history of geography and writings in the history of science upon the role of science as public culture and as popular 'polite' learning. The second, with reference to what is understood by the public sphere, considers the place of science as public culture in the eighteenth century in order to discuss *where* and *how* it was undertaken. If natural knowledge in a variety of discursive forms was an important part of public culture and private sociability and politeness in this period, was geography, however conceived of, likewise understood as a form of and a means to public knowledge? And if it was, where and how and for whom? These and other questions posed here arise from a concern to place the history of geography more centrally in contemporary debates on the history and situated nature of science. As illustration, two examples of geography in the public sphere are discussed. The first considers evidence for public lecture courses in geography and the private teaching of the subject throughout Scotland in the period *c*. 1700 to *c*. 1860. The second reviews the purpose and contents of a published attempt to bring geography to public audiences in early

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nineteenth-century Scotland and Britain, the *Edinburgh journal of natural and geographical science*, which appeared in three volumes between 1829 and 1832. Finally, with this context and illustrative material in mind, ideas about geography's place in the public sphere are used to prompt further questions about the situated nature — the geography — of polite and popular science in the eighteenth century and about the possibilities of writing a geography *of* the public sphere.

One start point is that recent work on the situated nature of scientific knowledge, including geography. Historians of science and of geography have considered the regional differentiation of scientific style and the comparative regional reception of key scientific theories such as Darwinism. Scientific practices in early modern Europe have been shown to have differing national, regional and even local expressions according to the nature of courtly cultures and patterns of overseas trade. National styles have been identified in botanical investigation, and attempts made to explore what some have seen as a 'cultural geography of science' at local scales. We may identify, too, the political topography of scientific commitment wherein scientific practices and different moral visions for science have been shaped by political persuasion, both across national institutions and within particular towns and scientific bodies.[2] Further work has examined the spaces of scientific knowledge: the museum, the library, Royal courts, lectures theatres and the pub have all been studied as sites for the production of rational knowledge.[3] This is not to see local sites as divorced from wider intellectual and social contexts or uninfluenced by distant geographies: work on eighteenth-century natural history, for example, has pointed to connections between that subject, the idea and practices of empire, and the role of men such as Joseph Banks whose London 'centre of calculation' ordered and shaped the new knowledges gained from South Seas voyages'.[4] Recognizing that scientific knowledge is a situated practical activity, that it has in a variety of ways a geography, demands that we consider seriously questions to do with the location and circulation of that knowledge. Amongst historians of geography, Livingstone has argued for attention to geography's situated nature. He has claimed that adopting an historiography for geography that "takes seriously the situatedness of knowing" would mean "abandoning normative history and looking to those contingent factors that shape ... scientific enquiry". Further, "It will mean locating particular geographical theories, methodologies, representations, schools of inquiry, and so on, in their intellectual context, their social space, their physical setting. And it will mean resisting the tendency to privilege certain definitions of the subject's conceptual terrain over others".[5] Examining such claims demands that if we are to understand in a particular historical context the spaces in which geography, however understood, has been produced, consumed and negotiated, we should not uncritically privilege the academic in considering the sites of its making and consumption. These sites, as the experience of Edmund Gosse above and others considered below suggests, may include domestic space, as they may also include the place of geography in institutions of popular and public science and in schools.[6] At least one commentator has drawn attention to the need to consider geography's non-academic spaces:

> But is it ever enough to concentrate on the big names, and on geography's own *institutionalisation*? And if, by their very humanity, all people are geographers, is it not reasonable to say that those of us who are privileged to be paid for the investigation and communication of something called 'geography' or 'geographical thought' could do worse than to examine, from time to time, its non-academic and even its vernacular roots?[7]

In considering, then, one aspect of geography's intellectual history, I am not exploring the relationships between formal geographical institutions.[8] My focus is upon the spaces occupied by the popular public consumption of geography before, in Britain anyway, the formal establishments like the Royal Geographical Society (1830) and university departments.

SCIENCE, NATURAL KNOWLEDGE AND THE PUBLIC SPHERE

The idea of the public sphere and the historical public production and consumption of knowledge is outlined in Habermas's influential *The structural transformation of the public sphere: An inquiry into a category of bourgeois society*, first published in German in 1962.[9] Habermas explained the rise of democratic polity within Western society with reference to the place of a literary and political bourgeois culture evident, most notably in the eighteenth century, in the production and purchase of printed books by a literate middling rank in society, by the rise of institutions and literary journals, and, above all, in the public promotion of reasoned argument as a means to the enlightenment of civil society. The principle of the public sphere was critical public discourse in which the bourgeois public was one of private individuals who joined in debate of issues bearing upon state authority. The public sphere in the political realm and in the world of letters was connected with the private spaces of the bourgeois family and its capacity to purchase and debate the products of public culture. This new critical sociability was situated — in coffee houses, lecture theatres and in new literary outlets — and dependent upon the territorial and political power intrinsic to the rise of early commercial capitalism. The institutions of the public sphere, important to any possibility of the geography *of* the public sphere as also for the place of geography *in* the public sphere, had several criteria in common: they preserved a kind of social intercourse that, far from presupposing equality of status, disregarded status altogether; discussion within such a public presupposed the problematization of areas that until then had not been questioned; and the processes that converted culture into a commodity established the public as in principle inclusive. For Habermas, the public sphere was, then, essentially an urban bourgeois phenomenon, was initially established in the world of letters before moving into the political realm, and was first apparent in Britain before becoming evident in France, Germany and America. His discussion also emphasized the importance of rational discourse and criticism and the connections between the State and the individual, mediated through such institutions, as integral to the birth of urbane civil society and to Western 'modernity' itself.

These claims have been subject to criticism on several counts. For some, Habermas's account is flawed for its emphasis upon a totalizing version of historical change, for not considering the possibility of there being more than one public sphere and for its failure to consider the production of the public sphere as at least in part relational, dependent upon connections with other discourses, notably plebeian cultures.[10] For others, criticism rests upon his lack of attention to gender. It is now clear that women were actively involved in the private and public consumption and production of natural knowledge, and that the Habermasian notion of the public sphere as "essentially, not just contingently, masculinist" is ill-founded.[11] Habermas has been criticized, too, for his relative inattention to the forms the public sphere took from the mid-nineteenth century and in the twentieth century with the rise of mass media.[12] He has also been criticized for his relative neglect of science in the public sphere.[13] This is, perhaps, surprising given, as Cooter and Pumfrey note, not only that "science can readily be fitted into the new public culture that Habermas sees as forged in such proto-political institutions as coffee houses and salons, and transmitted through the medium of newspapers and widely read literature", but also because his "theoretical perspective on the concept of 'publicity' enables us to see the preconditions of modern science as inextricable parts of the new public culture". Further, "the *publicization* of knowledge that he formulates must become an essential part of any explanation of the constitution of modernity where science is at the centre".[14]

It is now widely accepted that science was a situated public enterprise from at least the later seventeenth century. Shapin and Schaffer, for example, have shown how the formation of the experimental way of life in the early Royal Society involved the constitution of a relatively private space for experimentation and several supposedly public settings, usually involving an invited audience, for communicating its findings.[15] Stewart has documented the importance of London's coffee houses as sites for the promotion of Restoration science, even sketching in outline for James Brydges, later first Duke of Chandos, what might be seen as his local geography of public knowledge as he moved between Garraway's coffee house in Exchange Alley, Gresham College and the Royal Society.[16] Such public and private scientific sites, neglected by Habermas, are central to any notion of the geographies of scientific knowledge. They are also crucial to an understanding not just of the ways in which science promoted both knowledge of a thing itself but trust in the practitioner and reliance upon given means of enquiry and dissemination.[17] University professors, teachers and itinerant lecturers marketed natural knowledge in ways that made science a public commodity, capable of rational debate and of consumption by audiences whose reactions ranged from immediate comprehension of abstract principles, through admiration and sympathetic understanding to incredulity, or, as Benjamin Martin the well-known itinerant lecturer in Georgian England several times experienced, by threats to the lecturer's life.[18] Writing of Enlightenment England, Porter distinguished between the promotion of science via the commercialization of leisure, the rise in literacy and growth in book publishing, and the expansion of science as a matter of provincial culture. This provincial and popularized science had an uneven geography demanding further research: "In some places, scientific popularization, societies and even research throve; in some, it had a halting life; elsewhere, hardly any at all. Why the differentials? And who were the audiences, the enthusiasts for science?"[19] Others have documented the connections between natural philosophy and public spectacle in the eighteenth century with reference to the notion of scientific production as performance, an idea which demands critical attention to the audience, to the practices of public display, and to the rhetorics attached to the purposes to which knowledge was put. Practitioners might be seen by some "... as charlatans, possessed of base motives and gulling their vulnerable audience" and by others as "subversive radicals, undermining established authority and appealing to audiences hitherto excluded from the political nation".[20] Science lecturing involved working demonstrations in order, amongst other things, to affirm or not given views about the ontological bases to natural principles.[21] For Stafford, much of public science throughout Europe was a visual education affording amusement and instruction in spaces which were both public institutions and sites of private sociability.[22] Stewart's study of the rise of public science has shown how, in early eighteenth-century Britain, science was promoted via entrepreneurs such as Jean Theophilus Desaguliers and Francis Hauksbee through lectures and experimental displays in London's coffee houses and inns. Later itinerant lecturers such as Benjamin Martin undertook a similar promotion of natural knowledge in the towns of provincial Britain. Golinski has documented the practice and consumption of chemistry and reviewed its place as a particular form of utilitarian natural philosophy through which an articulate public, and the landed aristocracy especially, could improve themselves, their estates, and, ultimately, the nation.[23] An essential part of much public interest in science was concerned with utility, and, in eighteenth-century England and in France anyway, also with discourses of 'politeness'. Sutton, for example, has shown how the promotion of science in eighteenth-century France depended in large measure upon polite persuasion as to the usefulness of such natural knowledge to the élite and mannered social classes, a polite usefulness demonstrated, for men and women alike, through intimate participatory experiments. In England likewise, scientific knowledge and politeness, both as means and ends, were promoted through experimentation, the use of instruments and the rhetoric of polite conversation designed to instruct and to amuse and also to affirm politeness as part of a "program for modernity".[24]

Not only, then, was science widely practised as a form of public culture and private sociability in the eighteenth century: it had, in several senses, a geography: of *sites* of production, consumption and negotiation in London's coffee houses or Parisian *salons*; in some provincial towns but not in others; of experimental sites and *spaces of display*; of *private spaces* of polite conversation about experimental knowledge; of *the circulation of knowledge* between practitioner, author and audience; and of *practitioners themselves* on their itinerary. Such matters offer the possibility for exploring not just the situated geography of science as a form of public culture and, thus, the geography of the public sphere, but also the place of geography itself as a form of polite and public knowledge. As Golinski notes, "Rather than assuming the public nature of science, this perspective offers a rationale for empirical studies of the ways in which audiences are constructed and transformed in changing historical contexts".[25]

SITUATING GEOGRAPHY IN THE PUBLIC SPHERE

One commentator on public science in the eighteenth century has referred to that period's mathematical recreationists, empirical artists and popular science demonstrators as inhabiting a "shadowy world".[26] It is an apt term of geography's public practitioners and audiences then. Knowing that many geography books in the eighteenth century were produced for popular audiences as well as for more strictly utilitarian and commercial markets is not to know how else geographical authors acted to promote themselves and their subject.[27] Formal institutional records are sparse; itinerant lecturers or others augmenting their salary with public courses leave few traces outside of newspaper advertisements; and even where we can identify the spaces in which geography as a public discourse was given, and know the syllabus, it is difficult to know to whom they spoke and what the audiences' purpose was in attending. Fleeting glimpses are given: of the French geographer and physician Edme Guyot's public entertainments including geographical material in his eight-volume *Nouvelles recreations* (1772); of the public lectures in history and geography given in Paris in the 1730s by Noel-Antoine La Pluche, author of the hugely-popular *Spectacle de la nature*, published in nine illustrated volumes between 1732 and 1750. We know men like John Senex, the map- and globe-maker, gave public geography lessons in Georgian London and that Benjamin Martin, in his capacity as instrument retailer and itinerant lecturer, promoted geography as a "useful" subject to be understood better through "the Knowledge of the Use of the *Globes*, *Sphere*, and *Orrery*".[28] It is clear that geography in schools acted to prompt later interest in the subject: the poet Robert Burns, for example, who was taught surveying and geography at school, specifically demanded in 1791 that "the latest edition of Guthrie's Geographical Grammar" be included amongst books for his subscription library.[29] For Mary Somerville, author of *Physical geography* in 1848 (for which she was awarded the Royal Geographical Society's Victoria Medal), geography took place in school and at home: she recalls being taught geography by Mr Reed the village schoolmaster at Burntisland in Fife in 1791, how he came to the family home to teach her "for a few weeks in the winter evenings" and how such encouragement in and out of formal educational spaces together with her own study using the family globes was a great stimulus to her.[30] In Charleston, South Carolina in May 1733, geography was taught alongside other geometrical sciences "At the House of Mrs Delamare in Broad Street", as, from 1739 in the same town, a Mr Anderson was giving lectures on the "Science of Geography ... to any of the Gentlemen Subscribers to the Philosophical Lecture that shall please to attend". [31]

We know something of the publishing history of geography texts in the eighteenth century,[32] of geography texts in various Enlightenment encyclopedias,[33] and of the marketing of geography texts to popular audiences.[34] Geography, together with cartography, surveying, navigation and astronomy figured largely in the Royal Society's *Philosophical transactions* between 1720 and 1779, as part of an emphasis upon 'mixed mathematics' crucial to Britain's interests as a mercantile and imperial power.[35] Samuel Johnson and Edward Gibbon both saw useful value in what Gibbon called "rational geography".[36] And Johnson claimed, in a dedication to George III in George Adams's 1766 *Treatise on the globes*, that "Geography is in a peculiar manner the science of Princes". But if kings saw geography as a means to political authority, how, if at all, was geography used and understood in popular circles? Benjamin Martin reckoned geography an essential part of his *Young gentleman and lady's philosophy.* One of the book's dialogues between Cleonicus and his sister Euphrosyne concerns geography, with the latter clearly seeing it as an appropriate subject for a young lady: "You need not be afraid of my being tired with such useful and pleasant Studies as the Science of Geography affords; especially, as I apprehend the Use of Maps is so very considerable, that the greatest Part of our Pleasure on reading Books, that give us an Account of the Several Parts of the World, is derived from thence."[37] Beyond such hints, we know little of the ways in which geography was the subject of public interest and a means to stimulate popular knowledge of the world, whether it was so for men and women alike, and what values it was accorded by contemporaries.

Eighteenth- and early nineteenth-century Scotland offers rich potential for exploring geography in the public sphere, given widespread interests then in the problems of progress and virtue in a commercializing society and public engagement with the enlightenment of civil society.[38] Scotland in this period provided a cultural and intellectual environment "within which science could establish its civic credentials as public culture in close conjunction with the beginnings of its academic and disciplinary structure".[39] Evidence for courses of public lectures on agriculture, natural history and chemistry by university professors supports this claim, as does the use of museums as teaching spaces and sites for the display of utilitarian natural knowledge.[40] Geography was a formal part of university curricula in Scotland's universities about two centuries before the foundation of geography departments, being taught in cosmology and natural philosophy classes. In King's College Aberdeen, geography was a compulsory part of the curriculum in 1752, taught by the 'Common-Sense' moral philosopher, Thomas Reid, for whom the subject was part of that philosophy "which may qualify Men for the more useful and important Offices of Society, rather than merely making men subtle Disputants, a Profession justly of less value in the present Age".[41] Such evidence points to geography's longer-run and more diverse place in academic spaces and in the public sphere than existing historiographies suppose,[42] and hints at a demand for the subject amongst the public.

PUBLIC LECTURES IN GEOGRAPHY IN SCOTLAND, *c.* 1708–*c.* 1860

Detailed examination of Scottish newspapers and of university records in Scotland from the later seventeenth century to the mid-1800s reveals 76 different persons giving public lectures or private classes in geography in this period (Table 1). No one has been included here who taught geography in parish or burgh schools or who used such sites for public courses. Only those who explicitly advertised "geography" are enumerated, thus omitting many whose publicly-advertised courses in survey, navigation and astronomy may have included geography but for which there is no certain evidence.

Public geography classes were concentrated in Edinburgh and Glasgow with a scattering of courses in smaller centres of population (Figure 1). Evidence for the earlier public teaching of geography suggests that such courses began in Edinburgh and Glasgow and only latterly were apparent in the smaller towns. About twenty years before geography was being taught in the University of Edinburgh and in King's and Marischal Colleges in Aberdeen, a James Corss was running a public school in Edinburgh in April 1658 for the teaching of "Arithmetique Geometrie Astronomie and all uther airts and Sciences belonging theirto as horometrie Planimetrie Geographie Trigionometrie".[43] The data in Table 1 allow us to understand the place of geography in the public sphere for one national context, and, specifically, to be able to address four main issues: Who were geography's public lecturers? What was the nature of this public geography? Who were the audiences? What were the sites of its production and consumption?

Most persons delivering this public geography were self-styled as "teacher of geography" or "lecturer in geography". One or two such as the Rev. William Smart were parish ministers. Smart also gave private classes in mathematics, navigation, surveying and the "use of the globes celestial and terrestrial".[44] Some, like Thomas Blackwell and Robert Hamilton in Aberdeen, were university professors giving private classes and public lectures in geography, probably as a means to augment their salaries since university stipends were then largely dependent upon class size.[45] Others, like Robert Wallace and Alexander Watt in Glasgow in the late 1820s (Table 1: 71, 72), combined a professorial role at John Anderson's Institution (the forerunner to the University of Strathclyde) with public classes at home. In the case of John MackGregory, self-styled "Professor of Universal History and Geography" active in Edinburgh (and, possibly, in London) between 1707 and 1715, he used his title to substantiate his credibility. MackGregory advertised his lectures in the *Edinburgh courant* newspaper, in printed flyers and in the *Post man*, a popular news-sheet.[46] These were available in the sites of public discourse: "This Advertisement [that of 1713] is to be seen in all the Coffee-Houses in Town, and Copies on't are to be had from the Author at S. James, the Grecian, and Garraway's Coffee-Houses." A 1715 version announced that the advertisement could also be had from the author at the "Exchange and Caledonia Coffee-Houses". Little is known of this shadowy figure. His advertisement indicates he held a doctorate in law from Angers: he wrote four

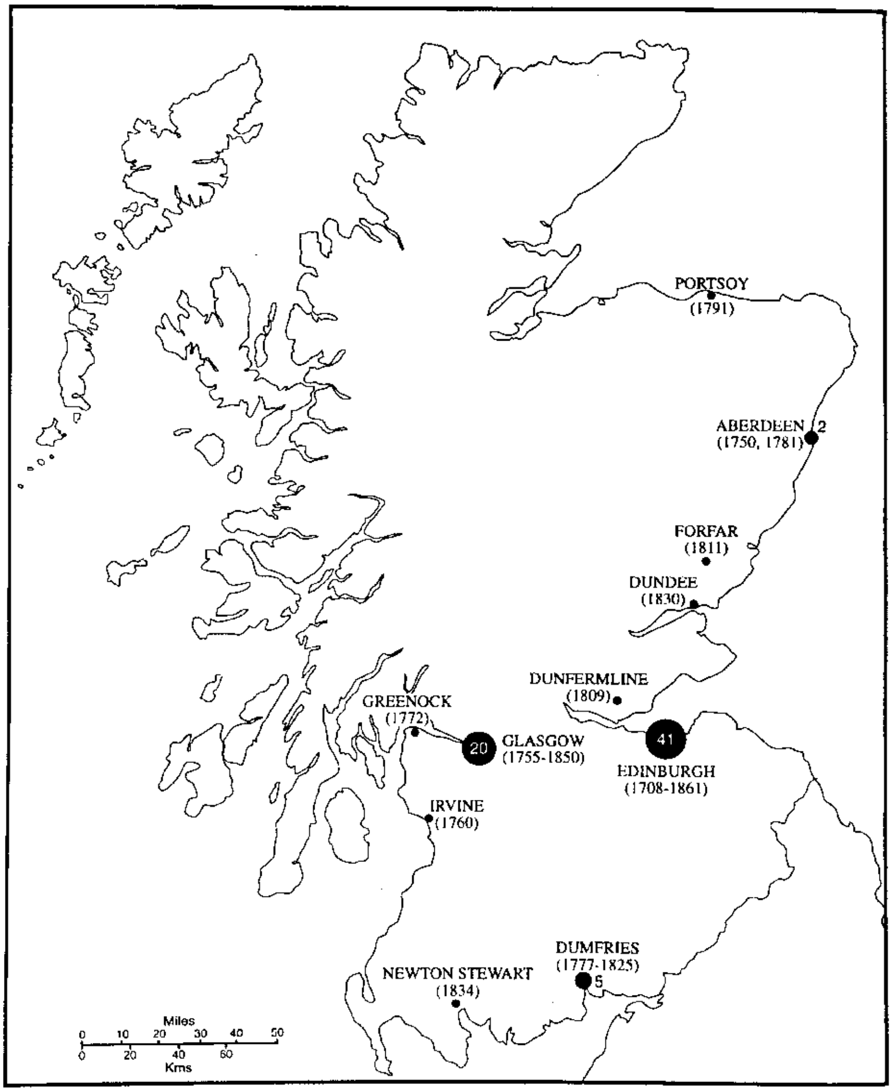

FIG. 1. The location of public lecture classes in geography in Scotland *c*. 1708–*c*. 1861 (for sources, see Table 1).

TABLE 1. Identified individuals giving public lecture courses in geography in Scotland, *c*. 1707 – *c*. 1861, by town, date and source of advertisement.*

Town, name of individual and brief description of course	Date of evidence/ advertisement
Aberdeen	
1. Thomas Blackwell, Professor of Greek at Marischal College	Private classes in geography, 1750s[1]
2. Robert Hamilton, Professor of Natural Philosophy and Mathematics at Marischal College	Public lectures including geography 1781–83 (*AJ*)
3. Thomas Gordon, Professor of Humanities at King's College	December 1761 (–1765?)[2]
Dundee	
4. Mr Mitchell, geography classes at 22 Union Street	1830 (*DPC*)
Dunfermline	
5. Assistant in a boarding school taught geography "for naval gentlemen"	1809 (*EEC*)
Dumfries	
6. John Brown, morning classes in geography	1810, 1814 (*DWJ*)
7. James Dinwiddie, "a travelling lecturer in mathematics, geography, mechanical philosophy"; uses the globe and the orrery[3] (Dinwiddie also in Edinburgh in 1778/79)	1777 (*DWJ*)
8. Mr Oliver, private class in geography and the use of globes	1825 (*DWJ*)
9. William Walker, classes on geography	1819, 1820 (*DWJ*)
10. Thomas White, mathematical and geographical classes	1788, 1794, 1801, 1802, 1813, 1816, 1818 (*DWJ*)
Edinburgh	
11. James Barclay, private teacher of geography	*c*. 1742 (*EEC*)
12. Robert Darling, private teacher of geography	1776, 1793–94 (*CM*; *EEC*)
13. James Dinwiddie, "Itinerant lecturer on natural philosophy, geography and astronomy"[3] (see also in Dumfries above)	1778, 1779 (*CM*)
14. George Douglas, taught "geography with globes and orrery, and navigation at 10 Blair Street, and, 1806–11, at 34 North Bridge	1795, 1806–11 (*EEC*)
15. Mr Douglas, taught geography and astronomy, 12 Queen Street	1845 (*EEC*)
16. John Duncan, teacher of geography in Libberton's Wynd	1773, 1788, 1793–94 (*CM*; *ED*)
17. Alexander Ewing (senior), teacher of geography, surveying and arithmetic; 40-lecture public class in geography	1756, 1768–82, 1790, 1793–94 (*CM*; *ED*)
18. Mr Alexander Ewing (junior) , taught geography and astronomy at 47 George Street "and also pupils at their own homes"	1837–61 (*EEC*)
19. Mr Forbes, advertised as teaching geography and other subjects through the medium of French	1743, 1752, 1755 (*CM*; *EEC*)
20. Mr Garden, teacher of Italian and geography	1790 (*CM*)
21. Mr Gentle, teacher of geography with globes, history at 5 Nicolson Square	1840 (*EEC*)

22. Rev. Gillan, teacher of geography and astronomy	1813 (*EEC*)
23. Alexander Ingram, teacher of geography, trigonometry and astronomy at Constitution Street in Leith	1800, 1815–28 (*EEC*)
24. John Innes, teacher of astronomy, navigation and geography	1730 (*EEC*), 1733, 1737 (*CM*)
25. Mr Knight, teacher of geography and astronomy for ladies	1827, 1828 (*EEC*)
26. William Laing, teacher of geography	1789, 1799 (*CM*, *ED*)
27. George Lindsay, geography for ladies	1816, 1818, 1831 (*EEC*)
28. Ebenezer MacFait, "teaching natural philosophy, mathematics and geography at the east turnpike of Mealmarket Stairs" (in 1754, 1760); mathematics, geography and astronomy at Kinloch's Close (1770) [also at four other addresses in the Old Town between *c*. 1746 and 1785]	1754, 1760, 1770 (*EEC*)
29. Mr McCulloch, teacher of geography, astronomy, and the globes for ladies "including use of lucernal, planetarium, orrery, terrestrial and celestial globes and other apparatus" at 6 South Castle Street	1821, 1822 (*EEC*)
30. John MackGregory, self-styled "Professor of Universal History and Geography"	1709, 1714 (*EEC*)
31. James Moir, teacher of geography and six other subjects	1761, 1789 (*CM*; *ED*)
32. Mr Moncur, taught geography, mathematics and navigation	1800 (*EEC*)
33. William Morison, taught geography, use of maps and charts, geography and navigation at Mr Ritchie's New Land, Blackfriar's Wynd	1801 (*EEC*)
34. John Morton, teacher of geography	1773, 1784 (*ED*; *CM*)
35. Mr Mylne, taught geography with globes	1817 (*EEC*)
36. Robert Nichol, teacher of geography (in Glasgow and possibly in Greenock 1781–82)	1786 (*EEC*)
37. William Noble, teacher of geography and navigation at 5 Nicolson Street (1813–20) and at 2 Drummond Street (1821)	1813–20, 1821 (*EEC*)
38. George Paterson, taught navigation and geography with the use of globes "in the solution of curious Geographical and Astronomical Problems" for about 20 years at his house at the foot of Horse Wynd	1747, 1751 (*EEC*)
39. James Philips, teacher of geography	1755 (*EEC*)
40. John Richardson, teacher of geography, 8 Dundas Street	1817 (*EEC*)
41. John Riddel, taught geography and navigation at College Wynd	1802 (*EEC*)
42. Mr Ritchie, teacher of geography, 50 George Street	1825 (*EEC*)
43. Thomas Scotland, taught geography, practical astronomy and navigation	1820, 1827, 1850 (*EEC*)
44. Rev. William Smart, Minister of Canongate Church	1708 (*EEC*)
45. Mr Stevenson, teacher of geography with globes, history	1800 (*EEC*)
46. D. Surenne, teacher of French, geography with globes, later lecturer in military history and antiquities	1815, 1817, 1835 (*EEC*)
47. W. Walker taught geography, natural philosophy and astronomy at Downie's Land, Carruber's Close	1794 (*EEC*)
48. Andrew Wallace, teacher of geography, navigation and popular astronomy	1815 (*EEC*)
49. Adam White, taught history, geography and astronomy at 79 South Bridge, then at 10 Nicolson Street, then at 3 St David's Street	1812–50 (*EEC*)
50. Mr Wood, 3-month astronomy, mathematics and geography course for 4-days a week; proposed to hold classes at Calton Hill Observatory	1795 (*EEC*)
51. Andrew Young, teacher of geography	1755 (*EEC*)
Forfar	
52. George Carey, teacher of geography and astronomy	1811 (*DPC*)

Glasgow

53. Matthew Adam, taught geography and mathematics at 2 George Street	1808–11 (*GH*)
54. W. C. and J. Craig, geography with globes for ladies at 33 George Square	1835 (*GH*)
55. John Cross, teacher of geography at Anderson's College, at 9 John Street and at 29 Ingram Street	1811–1820 (*GH*)
56. J. Cunningham, taught geography and mathematics at Brunswick Place, Trongate	1835 (*GH*)
57. James Denholm, 3 Argyll Street, is reported to have given a lecture course in physical geography and astronomy of 70 lectures "including the use of instruments" and "transparent apparatus": other involvements recorded include terrestrial and celestial globes and an orrery	1808–*c*. 1815 (*GH*)
58. Robert Dobson, "opened a school for accounts, arithmetic, algebra, geography with globes and astronomy" in the Old Coffee House Land	1755–61(*EEC*, *GJ*)
59. James Galbreath, taught geography at Buchanan's Hall	1764–65 (*GJ*)
60. John Gullan, gave a course of 25 lectures on geography, geology and astronomy to the Gorbals Popular Institution for the Diffusion of Science	1835 (*GH*)
61. Alexander Jack, teacher of geography, mathematics and navigation at McNair's back-land, Trongate (taught geography with William Gordon in the Gallowgate in 1759, and with James Scruton at Hutcheson's Hospital)	1764 (*GJ*) 1760 (*GJ*)
62. Robert Lothian, teacher at St Andrew's Entry, Saltmarket and latterly at the Trongate, of geography, mathematics, military mathematics and astronomy "with a set of improved machinery"; he is recorded as offering geography with globes and navigation and a ladies' geography class, using a planetarium, orrery, armillary and sphere and "other instruments made by himself"	1790–1801 (*GD)*
63. John McArthur, taught geography at Wood's Land, Trongate	1771 (*GJ*)
64. David Mackie, taught geography and "the globes" at 65 Wilson Street, 10 Cochran Street, 9 St George's Place (the Mechanics' Institution Hall), 54 St George's Place and 280 George Street	1820–35 (*GH*)
65. John MacNee, teacher of geography and surveying	1820 (*GH*)
66. James Morton, gave a lecture course of 63 "geographical" lectures in his Academy — much-cited use of equipment and other "demonstration apparatus"	1808–*c*. 1811 (*GH*)
67. Robert Nichol, teacher of geography, globes and navigation	1782–*c*. 1785 (*EEC*)
68. Rev. John Ritchie, classes in geography in the Glasgow Trades House schoolroom, 39 Glassford Street	1815–*c*. 1820 (*GH*)
69. Robert Scott, teacher of geography at an academy at 626 Argyll Street and at Candleriggs and Trongate	1811–15 (*GH*)
70. James Stirling, "geography with globes, surveying and navigation at the third storey of Old Coffee House Land" at Glasgow Cross 1758–1764 and at Steel's Land, Trongate, 1766	(*GH*)
71. Robert Wallace, Professor of Mathematics at Anderson's College but appears from *c*. 1828 to have given private courses in geography and other subjects, firstly at 7 South Frederick Street and then at 10 St Vincent Street	1832 (*GH*)
72. Alexander Watt, gave geography lectures at Anderson's College in which he termed himself "Professor" (in 1830) and had been teaching geography at 43 Dunlop Street and at 72 Buchanan Street (1820, 1825 respectively); also taught geography at Glasgow Academy, 153 Queen Street 1832	1820, 1825, 1860, 1832 (*GH*)

Greenock

73. Robert Nichol, taught geography, mathematics and navigation	1772 (*GJ*)

Irvine	
74. George Lesley, taught geography and seven other subjects	1760 (*GJ*)
Newton Stewart	
75. Nathaniel McCleary, itinerant lecturer on geography and astronomy	1834 (*DWJ*)
Portsoy	
76. James Hall teaching geography with globes and navigation	1791 (*EEC*)

*The initial data are derived from David Gavine (1982), "Astronomy in Scotland 1745–1900", unpublished Ph.D. thesis, Open University, 2 vols (data from vol. ii). The material in Gavine has been supplemented by further examination of newspaper records and of all university archives in Scotland.

Abbreviations used for newspaper sources:

AJ	*Aberdeen journal*
CM	*Caledonian Mercury*
DPC	*Dundee, Perth and Cupar advertiser*
DWJ	*Dumfries weekly journal*
ED	*Edinburgh directory*
EEC	*Edinburgh evening courant*
GC	*Glasgow courant*
GD	*Glasgow directory*
GH	*Glasgow herald*
GJ	*Glasgow journal*

1. Scottish Record Office, GD/18/5036 ff. 5,9,10,18. The emphases in this reference suggest it is likely these were given to private individuals not (alone) to university students in Aberdeen.
2. Aberdeen University Library, MS K 45, Minutes, vol. x, 1761–65, 63–64.
3. *Dumfries weekly journal*, 11 November 1777, p. 4A.
4. *Caledonian Mercury*, 13 June 1778, 2 January 1779.

books, *The geography and history of Lile* [Lille] in 1708, *The geography and history of Tournay* (1709), a similarly-titled work on *Mons* (1709) and a work on sepulchres, all dedicated to Prince Eugene of Savoy, published in Edinburgh "and to be Sold at all the Coffee-Houses in Town". He claimed his proficiency in geography to result from having "Travel'd over all Europe; ... having Liv'd at most of the Courts of Europe" and by "... having been Imployed in the Publick Business" [as a diplomat in Switzerland]. His four-page *ADVERTISEMENT to Gentlemen and Ladies* makes clear that, having now "come Home hither to his own Country, [he] does make Profession of Serving Gentlemen and Ladies by Teaching 'em MODERN GEOGRAPHY and UNIVERSAL HISTORY". His overall purpose was "to make One Understand the Descriptions and Accounts of what is to be Seen and Heard of in Traveling through the World". He considered geography, understood as facts about foreign countries, customs and descriptions as a didactic and utilitarian practice taught "so as to Make up the Want of Traveling to Those who have not Travel'd and to Supply them with the Next Best".[47] MackGregory was a self-promoter. Others like Blackwell, Hamilton and Gordon in Aberdeen (Table 1: 1–3) had a formal professorial position, yet seem, with the exception of Gordon who gave lectures on Ancient Geography as part of his teaching, to have delivered their geography out of hours to non-university audiences.

The diversity evident here certainly cautions against the easy categorization of persons giving public classes in geography. Heilbron distinguished four types of public lecturers in his work on the promotion of early modern physics: at the top, public lecturers associated with learned societies; a second class consisting of members of learned societies who set up independently of their institutions; a third group of "unaffiliated entrepreneurs, who taught in rented rooms, and the itinerant lecturers, who taught in public houses"; and, at the bottom, "the hawkers of curiousities, the street entertainers".[48] If we adopt this system for those promoting geography in the public sphere in Scotland, the great majority would seem to be of the second and third groups with a few, like MackGregory, as entrepreneurs on the make. But such a classification may too readily suppose a distinction between 'producers' and 'consumers' of geographical knowledge since as this evidence also suggests, much of this geography as public knowledge was promoted in private spaces.

Geography was produced and consumed in connection with other discourses. Most of those here identified taught geography in association with astronomy, navigation, geometry, mathematics and arithmetic. Astronomy and geography anyway had close associations: because of contemporary views which saw them as subjects suitable for a liberal and polite education; because of that more learned interest which saw them as crucial to maritime commerce and colonial expansion; because of the shared use made of terrestrial and celestial globes and other instruments such as the orrery; and, in this context perhaps, because of the close links in several university curricula between geography, cosmology and astronomy in promoting Newtonian science in Scotland from the later seventeenth century.[49] These matters are important for what they suggest about the moral and intellectual imperatives contemporaries then placed upon geography as a utilitarian practice. For some, it is clear that geography was understood as a form of and means to measurement, a type of mathematical practice quite in keeping with locally-evident interest in estate surveying, mapping and navigation.[50] Robert Darling, variously described as "private teacher of geography" and "teacher of mathematics and geography" in Ramsay's Land in late eighteenth-century Edinburgh "teacheth Youth Writing, Book-keeping, Mathematics, and Geography, and Gentlemen to Measure and Plan their own estates".[51] In this sense, the teaching of geography in the public sphere both directed and reflected the search for rational order and the reasoned improvement of individual and nation that underscored the place of an articulate public in Enlightenment Scotland and Europe. We might suppose, for example, that men like Robert Nichol in Greenock in 1772, Alexander Ingram in Constitution Street in Leith between 1815 and 1828, and perhaps even James Hall in the fishing village of Portsoy in 1791 (Table 1: 73, 23, 76), with his classes on geography and navigation, were, in such ports, promoting geography as navigational and locational discourse as a particular means to public utilitarian knowledge. Alexander Ingram was the author of a version of Euclid's *Elements*, intended for use in schools, and of *Principles of geography, containing the uses of globes, and a description of the different countries which are known to us* (1799), which went into a third edition by 1807. To judge from the contents of this book, the geography that he taught was about earth description, being able to use the globes and to know the major political and natural divisions of the earth's surface. Such evidence would suggest a strong emphasis upon utility and upon description of the world. But it also raises questions about the extent to which the nature of the geography produced was entirely a local matter, a product of a local context linking lecturer, audience, and the specific purpose to which the knowledge was to be put. As Ophir and Shapin have asked, what if the situated production of knowledge is a particularly local matter?[52] It is reasonable to suppose that some public courses in geography were shaped to the needs of local audiences: the production of knowledge is no less a matter of local supply and demand than other public culture. But the evidence here presented suggests that we should also think of this wider public regard for geography as part of commonly-practised discourses of mathematical utility and not alone a matter of local circumstance.

For others, perhaps even within the same audience, geography in the public sphere was a means to polite education, a way of promoting sociability through description of foreign countries, through informed use of the globes and measured discussion of maps in ways noted of science and sociability in eighteenth-century England and France. We are afforded some insight into *how* it was taught, not just through the public lecture as a matter of rhetorical exposition and warranted credibility, but through practical demonstrations and the use of apparatus. It is difficult to be precise in this respect since the advertisements are generally silent about the exact nature of teaching. But there is reference to the use of globes, terrestrial and celestial, and some mention of other equipment. In Edinburgh, for example, George Paterson used globes to solve "... curious Geographical and Astronomical Problems" in classes which ran over a period of twenty years (Table 1: 38). Robert Lothian, chaplain to Glasgow's Trades House in the late 1780s, taught his classes in geography, military mathematics, and astronomy with a set of "improved machinery" including a planetarium, an orrery and an armillary sphere, all made by himself (Table 1: 62). Many others were doing likewise (Table 1: 7, 13, 14, 21, 29, 33, 35, 45, 46, 48, 49, 50, 57, 64, 66, 70, 75). Bookshops were outlets for the purchase of globes as well as texts: Edinburgh's *Evening courant* on 20 January 1783, for example, carried news that "Martyne's New System of Geography" would be delivered to subscribers next week, that specimens of globes useful to understand the book were on display in a local shop and that "those who choose to advance the subscription-price, may have the globes as soon as they can be brought from London".[53] James Corss, teacher of geography in Edinburgh in 1658, made his own globes and other scientific instruments, and Robert Scott, self-proclaimed "Mathematician and Geographer" made globes for the Edinburgh cartographer James Kirkwood in 1804 and used them in his Commercial and Mathematical Academy as a means to promote navigation and surveying as useful subjects for "young gentlemen who are soon to enter into active life".[54] Using globes, maps and other 'geographical' apparatus in public lectures and in other places was almost certainly not the exciting experimental theatre that was the public lecture on electricity or medicine.[55] But the fact that such apparatus was used at all means we should not think of the production (and consumption) of geography as just a rhetorical and a textual exercise since it clearly involved instrumental learning and, we may assume, the promotion of useful world knowledge and polite conversation at one and the same time.[56]

Whilst we may infer audiences' intentions from the utilitarian and educational emphases to many courses, and from the instrumentally-mediated understanding of the terraqueous globe, it is not possible to know precisely who was attending and why. But several observations may be made. Some classes were attended by men seeking to enter university: Robert Wallace's lectures in Glasgow in 1832 treated geography as preparation for natural philosophy at the University of Glasgow. Entrance fees to lectures and classes, where they can be determined, were high enough to put off those of lower income. The emphasis upon practical utility suggests that surveyors, merchant traders, naval captains or those intending such employment were amongst the audience. Men probably predominated, but many public and private geography classes either included women or were specifically designed for women (Table 1: 17, 25, 27, 29, 54, 62). Alexander Ewing Senior, for example, ran his 40-lecture public classes in geography in Edinburgh on Mondays, Wednesdays and Fridays for men, and for women on Tuesdays, Thursdays and Saturdays, at a fee of a guinea for the course: similar courses were held annually for fifteen years from 1768 (Table 1: 17). Robert Lothian offered separate geography classes for women, complete with an array of instruments (Table 1: 62), but most others seem to have taught men and women together.

Not all geography aimed at the bourgeois public sphere. David Mackie's geography classes to Glasgow Mechanics' Institution in *c.* 1820 and John Gullan's 25-lecture course in 1835 to the Gorbals Popular Institution for the Diffusion of Science (which had opened in 1833 to provide popular lectures and a library) together suggest that geography was seen by some as useful popular knowledge for the urban working class, not just a pursuit of the bourgeoisie.[57] Certainly, that sort of audience and the type of knowledge being transmitted was very different from the social make-up and intellectual interests of the Royal Society of Edinburgh in the same period with its high proportions of landowners and professors within its earth science community.[58] In that regard, we ought not to see the public sphere as a single entity, nor consider popularity and audience participation to result just from a sought-after politeness or bourgeois notions of utility.

No single pattern predominates in regard to where the promotion of geography took place. MackGregory advertised his courses in Edinburgh's coffee-houses yet he lectured at his own lodgings and at his customers' homes. Indeed, for many so-called "public lecturers", their lecture courses and private classes were given in the lecturer's home. That this is so raises questions about the extent to which we can consider the production of geography in the public sphere a matter of separate private and public spaces, or, rather, conceive of geography's situated production in the public sphere as a blurring of distinctions between private and public *space* and between domestic space and *sites* of public learning. Certainly, I share Walters's intention "to suggest that polite science should be situated not just in the formal public sphere of the lecture, but also in the comparatively informal domestic scene of the home". For her, polite science in the domestic sphere manifested specific characteristics: an association between the social character of polite science and its topical content; the encouragement of women as active participants; and connections between the books and instruments of scientific learning and their display as objects of consumer culture: "polite science aligned the acquisition of socially appropriate kinds of scientific knowledge with the acquisition of material goods illustrative and symbolic of that knowledge."[59] Evidence for geography in the public sphere would seem to confirm these points, although it is difficult to know the extent of book and globe ownership amongst the several audiences here. The following extract on geography and astronomy from Alexander Monro's *The professor's daughter* (1739), subtitled *An essay on female conduct contained in letters from a father to his daughter*, illustrates many of these points and is of interest, too, for the father's closing strictures to his daughter about her making public her private learning:

> Whoever intends to read any History even the common news Papers ought to know the Situation of the different Countries, the Nature of their Climates, the Distances of the most remarkable Places from each other and the other particulars which are to [be] learned from Globes and Maps. This knowledge is what I call Geography. Without it one can not understand the different Claims and Interests of Potentates, the Causes of their different Connexions, of the gaining or losing of Battles, the difficulties or advantages of Armies or People in their Marches &c. A Months Application in this Study will make you very sensible how much People ignorant of it are blundering every day in common Conversation. I design to steal as much time from my other Business as to instruct you in this necessary piece of Knowledge by which I shall regain what I have forgot of it. I hope you will be as much entertain'd hereafter with the Globes and Maps as you was the other Day when I shewed you the more general things upon your small Set being brought home.
>
> I must think you ought to know as much of Astronomy as explains the common System and Motion of the Planets, if it was only to shun the Extravagancies and fears which many of your Sex so frequently express upon seeing an Eclipse or some such natural Appearance. Learn but so much as to read Fontenelle's Plurality of Worlds with pleasure. I engage to instruct you this far in five or six Lessons, but must give you the Caution never to discover this part of your Knowledge to your female acquaintances or the ignorant foplings of my Sex, for they will fix the name of Virtuosi, Pedant, and I don't know what on you.[60]

It is possible to suggest, then, that public institutions became sites of private sociability as individuals discussed matters of geography, and, at the same time, private spaces were used to debate and promote a geography that was seen as publicly useful. Because so much geography in the 'public' sphere involved the use of globes and other instruments, we perhaps ought not to see sharp distinctions between the home and the laboratory or, at least, between the home and the sites of experiment and display, a point noted of other contexts elsewhere.[61] To judge from those persons who used apparatus in their classes, at least part of their domestic space must have been given over for display and experiment or as a lecture room. This was not true for all: Thomas Longstaffe lectured in astronomy at Glasgow's Theatre Royal in 1825, for example, with an orrery about 10 feet in diameter, accompanied by music,[62] and others took their class to sites of learning such as an observatory (Table 1: 50). For the Rev. William Smart and his audience, the production and consumption of geography as public knowledge was certainly a domestic affair: "They may be instructed in the most useful problemes of geographie", his 1708 advert read, "... at their own house or at his own house in the head of the Canongate, ... or any other convenient place as the party shall direct".[63] But this evidence hints at considerable complexity in terms of the spaces in which geography was made as polite learning and public knowledge: of private spaces used for instrumental displays; of lecturers moving to their audiences and *vice versa*; of classes and teacher meeting in certain specialized sites, scientific or popular; and, not least, of trips to the shops to purchase texts and instruments. Several of those geography lecturers in Edinburgh and Glasgow continued to promote the subject as they relocated within the city (Table 1: 14, 28, 37, 49, 55, 61, 62, 64, 69, 70, 71, 72). In two cases we can identify itinerant lecturers moving between towns or within a locality (Table 1: 7, 75). James Dinwiddie advertised his course of lectures on "the principles of Geography and Astronomy" to be explained "on an elegant eighteen inch *Globe*, of a new construction, and the ORRERY" in Dumfries in November 1777, at which time he also signalled an intention to give classes in French, mathematics and experimental philosophy.[64] The next year and again in 1779, he was advertising his natural philosophy, geography and astronomy classes in Edinburgh.[65] What little is known of one Nathaniel McCleary in 1834 merits inclusion in full for what it illustrates about the connections between subjects, the way even a self-taught artisan promoted geographical knowledge through the use of instruments, and, in this case, for what it suggests about the geographical mobility of some of those working in the public sphere:

> The inhabitants of Newton-Stewart and its vicinity, have lately been highly entertained by a course of lectures on Astronomy and Geography, delivered by Mr Nathaniel McCleary, a self-taught Astronomer, and a native of the banks of the Cree. Mr McC has for many years past assiduously applied himself to the study of the above sciences, in the course of which time, although labouring under great disadvantages — he is of the number of those who earn their bread by the sweat of their brow — he notwithstanding has made himself acquainted with the theories of all the ancient, as well as the principles of the most eminent modern Astronomers. His first lecture, on Friday evening, the 28th March, was on the Solar System, in the course of which lecture he exhibited a mechanical

> figure, the workmanship of his knife, which showed the situation of all the primary planets from the sun; as also the satellites from their central bodies. The second night he lectured on the fixed stars; the third and last night on Geography. In his lecture on the latter science, he exhibited an astonishing strength of memory.
>
> Mr McC. intends in the course of the present summer, visiting the principal towns in the Stewurtry and shire of Galloway. We wish him success, as he seems to deserve it; and also as a wife and family are dependant on his exertions.[66]

Not all geography's public lecturers, then, were located in the centres of population, used manufactured instruments and treated lecturing as a means to urbane sociability. Such evidence points also to the ideas of *circulation and movement* — of ideas, of books, of instruments, of lecturers, of their audiences and even of their families — in understanding geography's place in the public sphere.

PUBLISHING FOR THE PUBLIC SPHERE: THE *EDINBURGH JOURNAL OF NATURAL AND GEOGRAPHICAL SCIENCE*

This journal, published in Edinburgh and distributed there and in London and in Dublin, appeared in twenty-one monthly parts between October 1829 and June 1831, under the editorship of two Edinburgh men of science, William Francis Ainsworth, President of the Royal Physical Society of Edinburgh and former President of the Plinian Society there, and Henry Cheek, formally involved with the city's Royal Medical Society and with the Caledonian Horticultural Society amongst others. Both were graduates of the University of Edinburgh. Ainsworth trained as a medical student but never practised. Prior to editing the *Journal* he had travelled widely in France in search of data in support of the Huttonian theory. He was a founder member of the Royal Geographical Society in London in 1830, was physician-naturalist on Chesney's 1835 Euphrates expedition, on which he earned the nickname "Young Strabo", and travelled widely in Asia Minor.[67]

What is important here is less the credibility of the editors, but the *Journal*'s purpose, contents, and intent to promote "Natural and Geographical Science" for the public. As the "Preface" to the first part stressed, the *Journal* presumed a validity for and interest in natural science and geographical knowledge, and considered such work should be available to all:

> The Edinburgh Journal of Natural and Geographical Science was instituted with the view of supplying a deficiency long contemplated with regret by all men of science and information. That no periodical, devoted to the prosecutions of geographical enquiry, and the careful collection of the important facts which every month brings forth, was to be found in this country, seemed to argue a degree of supineness very inconsistent with the character of the nation: that natural science should be the exclusive property of those only who could afford

> to purchase the expensive periodicals of the day, appeared to be an injustice to the public, and a drawback on the progress of knowledge, which ought no longer to exist; and that the cumbersome quarterly publications should occupy the wholefield, "dragging their slow length along," was evidently incompatible with that anxious desire for information, which is now felt by all ranks and classes in this country.
>
> This Journal, was, therefore, established for the purpose of affording to the public, with the requisite rapidity, in a condensed form, and at a cheap rate, those discoveries and observations, which could hitherto only be arrived at, by a slow process, at a high price, and in a form the principal merit of which seems to be the respectability of its bulk: and we invite the public to open this volume, and judge how far we have executed our design.[68]

In advertisements accompanying the launch of the *Journal*, the point about the public promotion of natural and geographical science was again stressed:

> A leading consideration which actuates the Editors of this Journal is, that Science ought to be no longer hidden under the covers of expensive volumes, and prostituted to the unworthy elegances of mere gain. They wish their numbers, uniting cheapness with elegance, at the same time to be found in the mechanics' cottage and on the table of the scientific soirée. Therefore, and at a moderate price, and in a condensed form, they propose to publish the novelties of the day.[69]

The *Journal* had a particular ideological and political commitment to public knowledge, a commitment which might have placed the *Journal* in commercial if not also in intellectual opposition to other scientific periodicals such as, in Edinburgh anyway, the *Edinburgh review*, the *Transactions* of the city's Royal Society, and *Blackwood's magazine*. As Shapin has shown, Edinburgh in the 1830s was a key site for the promotion of science to the public.[70] In fact, most newspapers and competitor periodicals informing the bourgeois public sphere in Edinburgh welcomed the *Edinburgh journal*. The *Edinburgh observer* had "... no hesitation in saying that there is room for a publication of the kind", and, in reviewing Part V, that journal commented "The Journal of Natural and Geographical Science continues to hold up its head with dignity, and promises to turn out a formidable rival to its more bulky contemporaries". By March 1830, the *Journal*, for one rival in the city's literary public sphere, "... begins to figure as a star of the first magnitude in the often turbid heaven of Athenian [i.e., Edinburgh-based] science".[71] The *Journal* organized its contents around three main headings: Original Articles; Collections of Facts; and Analyses of New Books and Papers. The first section included full-length papers, summaries of papers printed elsewhere, and papers on "controversial subjects" with authors' names, in order "to limit that kind of discussion which, under an anonymous form, occasionally disfigures the pages of scientific works".[72] The Collections were divided into six listings: geographical, geological, anatomical, botanical, mineralogical, and chemical. A further infrequent section reported on the proceedings of scientific institutions throughout Britain and overseas. Several themes, however, do merit comment.

The attention paid to the proceedings of scientific institutions ensured that public audiences in London, Edinburgh and Dublin knew what was being debated in scientific circles there and in European cities and provincial bodies throughout Britain. Attention was paid to the business of the Geographical Society of Paris and, from 1830, to the formation and public role of the Royal Geographical Society in London: "We did not anticipate when we commenced our labours, ... that we should so soon have the pleasure of announcing the intended formation of a Geographical Society in London", noted the editors in May 1830, "... and we can only say for ourselves, that our voices and pens will be devoted to its advancement". As a later part noted,

> Indeed, we shall make it a duty to keep our eye constantly fixed on the progress of this Society, which is so intimately connected with the objects of our periodical; and we feel assured that its directors will take every opportunity of enabling us to extend the knowledge of their invaluable undertaking. We would wish to identify ourselves, in a measure, with the Geographical Society of London, which may thus stretch out its own arm to the remotest corners of the land.[73]

For historians of geography, such evidence highlights a context to the origins of the RGS not hitherto identified.[74] It also suggests that the *Journal* helped make its own public, both through having a particular intention upon publication, and, in a related sense, by meeting that audience's expectations through attention to geography and natural knowledge. This was not, however, only a local Edinburgh public. The *Journal* saw itself as part of networks of information operating nationally and internationally as well as locally. For example, it carried extracts from Baron Cuvier's lectures on the history of the natural sciences given to the Parisian Académie des Sciences. It carried information about local public lectures and demonstrations in science, notably in chemical science but also Ainsworth's own public lectures in geology and physical geography, in which he related fossil evidence "to the new Theories of the Earth".[75]

The *Journal* also afforded a means by which the public gaze could be turned upon the private and professional practice of science and upon the academic spaces of its production. The first in a series of articles "On the present state of science of Great Britain" examined the University of Edinburgh's Natural History Museum, held and supposedly managed as a research and teaching collection for the collective good by the University's Natural History Professor, Robert Jameson, but, in effect, treated by him as a private resource. Henry Cheek had been refused access to the collections, Jameson regarding it as private property. Ainsworth, as a follower of Hutton, had no time for Jameson. Further, the University refused public access to these materials and charged members of the public an admission fee to the Museum.

Public knowledge was being strongly influenced by the authority of private individuals and institutions. As the editors noted, "do not the public permit these specimens to be deposited in their rooms, on the understanding that they are for public use? and is a servant of the public [i.e., Cheek] to be spurned when he respectfully requests permission to see his master's goods?" [76] They campaigned through the *Journal* to allow free public access on certain days. Personal circumstance clearly motivated them as did Ainsworth's commitment to Huttonian theory and opposition to Jameson's Wernerian Natural History Society.[77] "We do not hesitate to say, that it was the practical instance of prevention which we personally experienced, that stimulated us to an undertaking which is called "public-spirited". We wish that a spirited public, had by prior exertion, relieved us of the unpleasant duty."[78] The greater motivation was that commitment to public knowledge which had led them to found the *Journal*, a commitment which demanded attention to the public's access to what others regarded as private spaces of knowledge. This *was* a local matter, then, not just in the editors' view about one specific site of natural knowledge in Edinburgh, but in the ways in which they used their publication to constitute rather than to reflect a view about public science.

In order to secure reader loyalty and to make the contents understandable to their intended audiences, attention was paid to an appropriate rhetoric. As Cheek put it, "A Popular scientific periodical addresses itself to two classes of readers so entirely distinct, that it becomes necessary to assume therein a style and language appropriate to each".[79] The *Journal* also tried to organize a meeting (never realized) of Scottish naturalists, to be held in Edinburgh, which was intended not only as the largest gathering then held of naturalists but to enhance Edinburgh's status as a site for the promotion of science, and, thus, Scotland's reputation: "Our southern friends had better be on the *qui vive*, for the metaphysical nation is becoming clear-headed, and threatens soon to take a lead in the cultivation of natural science."[80] It also contributed to public engagement with geography by allowing an outlet for non-specialist writers. Many essays carried were by distinguished contemporary natural scientists. James Bell, however, who wrote articles on errors in the works of Oriental geographers, on the geography of Russia, and notes on other topics,[81] was a failed cotton manufacturer from Jedburgh in the Scottish Borders who had turned to geographical writing to pay his debtors. He wrote papers on physical and mathematical geography for the *Scots mechanics' magazine*, produced in Glasgow for the Mechanics' Institution.[82] He wrote two books: *Critical researches in philology and geography* (1824), and in 1832 in six volumes (it appeared in volume parts from 1830 onwards), *A system of geography, popular and scientific, or a physical, political and statistical account of the world and its various divisions*, which drew heavily upon the Danish geographer, Conrad Malte-Brun, and his 1822 *Universal system of geography*.

What, in summary, should we make of this journal's "enthusiasm in the cause of a noble and favourite science"? We cannot determine either circulation and subscription rates, or patterns of readership: did private individuals buy it? Was it bought for Mechanics' Institutes or other sites of popular learning and read aloud or privately and silently consumed in domestic spaces by the same persons who attended private classes in geography? It was important enough to be included in other scientific periodicals, in Edinburgh anyway, but this may have meant it got only as far as scientific soirées there, not to the mechanic's cottage. The price of two shillings per monthly part probably would have restricted access by the less well-off. Sales levels and the likely costs of the several coloured plates included in later issues may have contributed to the journal's short lifespan. What we can say is that, in the *Edinburgh journal*, we have evidence of trained scientific men in Edinburgh and further afield seeking to promote geography as a form of popular public knowledge in periodical journal form rather than through lecture, public demonstration, or private class. The journal was broadly welcomed by its competitors, regarded by contemporary natural scientists as an appropriate outlet for their work, and written in ways which paid attention to the different rhetorics needed for its diverse audience. It was locally situated but bound up with the national and international circulation of knowledge about geography and with the institutions directing that knowledge in Paris, Berlin and in London. The editors also used it to shape, almost actively to constitute, public opinion about the sites in which knowledge took place and about the relationships between the academic spaces for the promotion of science and those of its public consumption and negotiation.

CONCLUSION

There were several ways, then, in which geography was situated as polite public knowledge in the public sphere of the 'long eighteenth century'. Numbers of persons have been identified in Scotland giving private and public classes in geography, chiefly and initially in Edinburgh and Glasgow and in smaller centres of population. The sort of geography being delivered varied greatly: from description of countries and identification of principal features, to more detailed utilitarian discourses in which context geography was commonly delivered in association with astronomy, geometry, mathematics and navigation. Such discursive connections are to be explained with reference both to the utilitarian emphases placed upon natural knowledge in general and to the local circumstances of audience and lecturer. Geography's production was, largely, a textual and rhetorical affair and, to a lesser extent, was a matter of performance and display involving instruments. Utility was not just economic or even directly material. For some, geography, however understood — as global description of places one might never visit, or as a practical science designed to help one plan one's estate or navigate safely — was a means to public learning *and* private polite sociability. This was a matter of collective and individual importance for members of the public treating the didactic use of globes or purchase of journals such as the *Edinburgh journal of natural and geographical science* as a means to self-improvement. It was also a matter of personal importance to those doing the teaching, especially perhaps for men such as MackGregory whose own credibility rather than his audience's demanded that he call himself "Professor". Finally, geography in the public sphere was a situated practice in terms of the spaces of its production, consumption and negotiation. For a few persons, it took place in academic spaces given over briefly to public knowledge. For others, geography was a collective social enterprise that took place either in the semi-public space of a town hall or a lecturer's self-styled "Academy" or in the private spaces of the lecturer's own home in ways which suggest that scientific knowledge in the public sphere was, in certain ways, a domestic undertaking.

Such evidence has wider implications for our understanding of the situated nature of geography and of science in the past, of the idea of the public sphere as a means to explain the place of knowledge outside the academic realm, and, more broadly, for consideration of there being a geography *of* the public sphere. If taking seriously the spaces of geographical knowledge may "enable us to be less defensive, because less essentialist, about geography's conceptual space",[83] it may also demand that we should more explicitly consider the ways in which geography took shape outside the academy. Instead of considering geography's history as a contested narrative connecting disciplinary academic spaces, it might be considered as a matter of certain geographies in particular spaces, a geography or historical geography of geography, in which certain discourses found (or not) particular analytic purchase by being judged worthy as a form of public knowledge, of private learning or as a subject worth advocating in popular periodicals. This may demand that we do not just claim that geography or science has a geography, but that we show how and where and do so by grounding empirical work in appropriate historical and theoretical context. This may, in turn, lead to recognition of the localist character of the audiences, the particular nature of credibility attached to certain sorts of geography, and to the ways in which that geography, perhaps in association with other means to knowledge and to local sociability, had the meaning it had. In one sense, for example, the emphasis of the *Edinburgh journal* in promoting geography as a form of public knowledge in Edinburgh and more widely in the 1830s was quite in keeping with the local context for the position of science in that city then. Henry Cockburn's remark on the establishment in 1832 of the Edinburgh Association for Procuring Instruction in Useful and Entertaining Science, indicates the mood of the times: "It is a sort of unendowed college, where lectures are given to all, male or female.... The lectures are in botany, geology, chemistry, astronomy, physiology, natural philosophy, phrenology, and education.... It is a very useful establishment, giving respectable discoures very cheaply to a class of persons for whose scientific instruction and amusement there is no other provision ... it is gratifying to see hundreds of clerks and shopkeepers, with their wives and daughters, nibbling at the teats of science anyhow."[84] In another sense, what was happening in Edinburgh was part of a widespread interest in public knowledge in Britain in which public science was "a mode of useful knowledge, an instrument of self-improvement, an aid to profitable, rational, and usually individualistic economic activity, and a pillar of natural religion".[85] And in yet further ways, the evidence of James Bell in Edinburgh, of David Mackie and John Gullan in Glasgow in the late 1820s and 1830s and of the *Edinburgh journal* suggests that these wider interests in public science were reflected in the locally-situated production and consumption of geography as one particular form of knowledge. And this is to recognize, too, that matters to do with the historical *relations* between science and the public should consider how those entities were themselves mutually *constituted*.[86]

Such complexity, I suggest, means we should be cautious about use of the term 'public sphere' to understand geography's place as a form of public knowledge. The fact that geography was so clearly part of bourgeois public learning in the eighteenth century and part of an early Victorian emphasis upon useful knowledge for the urban working classes suggests several publics to have engaged with geography. There were different audiences for different sorts of geography and different versions of credibility and purpose being articulated. Habermas recognised distinctions *within* the audiences of the bourgeois public sphere, between the concert-going public and the theatre-going public, for example.[87] But he paid little attention to other audiences and to the ways in which public science, with its performers and different audiences, was so firmly set within particular contexts. Geography's promotion as a form of public knowledge occurred not only in those institutions of sociability central to the Habermasian notion of *the* public sphere, but in a variety of other spaces, notably the home. For geography anyway, its place as a credible form of natural knowledge depended upon allowing public access to private spaces, either the home of the lecturer or, indeed, of his audience, and in the wider sense of affording access to the public display of scientific specimens. This is, as I hope to have shown, a matter of local context and meaning. It is also a matter of the connections *between* local sites and spaces of meaning: between the coffee house in which MackGregory's advertisements were posted, the rooms in which his and other classes were held, the local bookshops where geography's books and instruments could be purchased, and the newspapers and journals in which literate individuals could learn of geography's production in such ways. It is about the ways and the spaces in which men and women came together as private individuals to form a public sphere.[88]

The idea of a geography *of* the public sphere was not considered by Habermas, at least not in the sense in which we might consider the *salons*, coffee houses and scientific institutions as particular *sites* for the promotion of public discourse with different audiences and means to the *circulation* of experimental and other information. Yet some recent attention to the public sphere has begun to recognize its geographical character. Dena Goodman has noted how "During the last six years there has been substantial debate about the validity of Habermas's theory: ... Questions have been raised about the possibility of multiple publics beyond the literate, 'bourgeois' one privileged by Habermas, about women's role in the public sphere and their relationship to it, and about the way in which the national cultures of England, France, and Germany figure in Habermas's basically Marxist terminology, which sees England as in the lead and Germany pulling up the rear".[89] Other work on the nature of the public sphere in eighteenth-century Russia, Germany and

Britain has demonstrated the different connections between ideas of national identity and the public sphere in ways which, if only at the level of individual nations within Europe, nevertheless allow for the possibility of considering more complex geographies of the public sphere.[90] This is not, however, simply to treat geography as a locational or figurative rhetoric that, to cite Goodman, "... enables us to map the cultures of the century we study and to interrogate them".[91] It is, rather, to consider the geography *of* the public sphere as a way of understanding the particular and situated nature of institutionalized social life and scientific enterprise, popular and polite, in given contexts. Geography as one form of public knowledge would fit within this conceptual schema in ways I have sketched here. To be fair, Habermas's conception of the public sphere was much more concerned with the *historical* bases to modernity than with their *geographical* expression. Yet it is possible to see that the public sphere was in several ways geographically constituted. Habermas claims, for example, that it was the dissolution of the feudal order by long-distance commerce that played a key role in prompting those changes that produced the public sphere; it was the growth of an urban culture — of concert halls, philosophical societies and so on — and the development of local forms of governance and popular culture which allowed the expansion of the public sphere. As Eley has noted, "The breaking down of parochial identities and the entry of rural societies into national political cultures, or the nationalization of the peasantry ... is in one dimension the creation of local public spheres and their articulation within a national cultural and political arena".[92] Such matters — of site, of local urban context, of the movement of ideas and of people and intellectual goods, of the situated display and performance of public and private knowledge — hints indeed at the ways in which we might conceive of the geography, even geographies, *of* the public sphere.

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43. Michael Wood (ed.), *Extracts from the records of the Burgh of Edinburgh* (London, 1940), 93.
44. *Edinburgh courant*, 31 March–2 April 1708. Smart receives only brief attention in A. Law, *Teachers in Edinburgh in the eighteenth century* (London 1965), 170–1.
45. John Morrell, "The University of Edinburgh in the late eighteenth century: Its scientific eminence and academic structure", *Isis*, lxii (1971), 158–71.
46. *Edinburgh courant*, 3–6 September 1707; 4–6 October 1708; *Mr MackGregory's Advertisement to Gentlemen and Ladies* (London 1713) [and 1715]; *The postman*, 20 October 1715.
47. *MackGregory's ADVERTISEMENT to Gentlemen and Ladies* (London, 1715). In a letter of 12 March 1722 to Sir Hans Sloane, MackGregory seeks in a rather desperate rhetoric Sloane's patronage: "... being now returned to London in a very poor ... way begs ... to apply to your generosity that you may please to give him what you think proper to [support ?] him in his present necessity": British Library Sloane MS 4046, f. 213. A later letter of 23 October 1722 uses almost exactly the same phrasing in seeking support from a patron in Cambridge: British Library MSS Add 22,911, f. 256. It would thus appear that the only certain thing we can say of MackGregory is that his geography did not sufficiently reward him.
48. John A. Heilbron, *Electricity in the 17th and 18th centuries: A study of early modern physics* (Berkeley, Calif., 1979), 158.
49. Withers, *op. cit.* (ref. 41), 115; David Gavine, "Navigation and astronomy teachers in Scotland outside the universities", *Marriner's mirror*, lxxvi (1990), 5–12.
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51. *Caledonian Mercury*, 1 June 1776, 1a.
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55. A point reinforced by other work on scientific lecturing in this period: see ref. 20 and Roy Porter, "Medical lecturing in Georgian London", *The British journal for the history of science*, xxviii (1995), 91–100.
56. Law, *op. cit.* (ref. 44), 172 notes that Ewing was in his early days a teacher of writing, arithmetic and book-keeping, and that he wrote a popular textbook on arithmetic for schools. By 1759 Ewing was concentrating more on surveying, navigation and the use of an orrery, globes and maps; *Caledonian Mercury*, 15 October 1759, 17 December 1768; *Edinburgh evening courant*, 3 May 1783. That this is so raises more general questions about how these self-styled "teachers" and "lecturers" of geography in the public sphere either taught themselves or were taught the geography they taught others. On this point more generally in relation to the popularization of science, see Richard Whitley, "Knowledge producers and knowledge acquirers: Popularisation as a relation between scientific fields and their publics", in Terry Shinn and Richard Whitley (eds), *Expository science: Forms and functions of popularisation* (Sociology of the Sciences Yearbook, ix; Dordrecht and Boston, 1985), 3–28.
57. Marwick dates the establishment in Scotland of Mechanics' Institutes to the early 1820s with the establishment of the Edinburgh School of Arts (1821) and the Glasgow Mechanics' Institution in 1823, with the originator being Thomas Dick, Master of the Session School at Methven in Perth, himself a popular writer on astronomy and philosophy: William H. Marwick "Mechanics' Institutes in Scotland", *Journal of adult education*, vi (1932–34), 292–309. A contrary opinion dates the movement to the early nineteenth century and for the stimulus to have come from George Birkbeck, Professor of Natural History in Glasgow 1799–1804: see J. C. Jessop, *Education in Angus* (London, 1931), 296–7. Limited surviving evidence from the 1820s favours Marwick's interpretation: the 1827–28 Third Report of the Dunbar Mechanics' Institution printed and published by James Miller in Haddington in 1828 shows that a class for geography was opened in Dunbar in October 1827 and was still operating a year later. For a broader review of the place of mechanics' institutions and the popularization of natural knowledge, see also Ian Inkster, "The social context of an educational movement: A revisionist approach to the English mechanics' institutes, 1820–50", *Oxford review of education*, ii (1976), 277–307; and see also Cooter and Pumfrey, *op. cit.* (ref. 14), 241.
58. Steven Shapin, "The audience for science in eighteenth century Edinburgh", *History of science*, xii (1974), 95–121.
59. Walters, *op. cit.* (ref. 24), 122.
60. P. A. G. Monro, "Introduction, and The Professor's Daughter", *Proceedings of the Royal College of Physicians of Edinburgh*, xxvi (1996), 1–189, p. 19. In a note in the original manuscript account, Alexander Monro records that on Friday 16 January 1741, John Monro, Margaret's eldest brother, "gave an oration on Geography to the youthful 'Latin Society' which met each evening in the Professor's room: the written account was corrected by his father" (P. A. G. Monro, *op. cit.*, 185, n. 37).

61. Shapin, *op. cit.* (ref. 15, 1988); Owen Hannaway, "Laboratory design and the aim of science: Andreas Libavius versus Tycho Brahe", *Isis*, lxxvii (1986), 585–610.
62. *Glasgow herald*, 1 April and 5 August 1825.
63. *Edinburgh courant*, 31 March to 2 April 1708.
64. *Dumfries weekly journal*, 11 November 1777, 4A.
65. *Caledonian Mercury*, 13 June 1778, 2 January 1779.
66. *Dumfries telegraph*, 16 April 1834.
67. L. C. Sanders (ed.), *Celebrities of the century* (London, 1890), 45. Ainsworth wrote or edited a number of works, of which three are relevant here: *Researches in Assyria forming the labours of the Euphrates expedition* (London, 1838); *All round the world: An illustrated record of voyages, travels, and adventures in all parts of the globe* (London, 1860) which he edited, as he also did the *Illustrated universal gazeteer* (London, 1860). The quote describing him as the "Young Strabo" is from John S. Guest, *The Euphrates expedition* (London, 1992), 43.
68. *Edinburgh journal of natural and geographical science* [hereafter *EJ*], i (1829), Preface.
69. This phrasing does not appear in the printed Preface to the first number of the *EJ*, but appears in a separately printed and scarce Prospectus advertising the *EJ* and bound in with the first full volume. The quote is from p. 4 of this Prospectus, contained with the copies of the *EJ* held by the Library of the Royal Botanic Gardens in Edinburgh: I am grateful to the Librarian of the Royal Botanic Gardens Edinburgh for bringing this to my attention.
70. Steven Shapin, "'Nibbling at the teats of science': Edinburgh and the diffusion of science in the 1830s", in Inkster and Morrell (eds), *op. cit.* (ref. 2), 151–78.
71. *Edinburgh observer*, October 1829; *Edinburgh literary journal*, 6 March 1830.
72. *EJ*, May 1830, 158–9.
73. *EJ*, August 1830, 433.
74. On the origins of the RGS, see Hugh R. Mill, *The record of the Royal Geographical Society* (London, 1930); David R. Stoddart, "The growth and structure of geography", *Transactions of the Institute of British Geographers*, xli (1967), 1–19.
75. See also the lectures by Thomas Kemp, lecturer in chemistry: *EJ*, December 1829, Article IV, Experiments on exciting Galvanism, with compound and simple substances, at high temperature 183–186; Kemp had further adverts in *EJ*, 2 April 1830.
76. *EJ*, December 1829, 169, 271.
77. Ainsworth's distinctly anti-Wernerian views, his opposition to the Wernerian Natural History Society and his anti-Jamesonian views are made clear in *EJ*, February 1830, 352–5, and in two articles under the general heading of the "Present state of science in Great Britain" in *EJ*, July 1830, 269–74.
78. *EJ*, December 1829, 275.
79. *EJ*, December 1829, 161.
80. *EJ*, June 1830, 234.
81. *EJ*, November 1829, 81–91; August 1830, 259–62, 329–40, 416–24.
82. Robert Wallace (ed.), *The Scots mechanics' magazine* (Glasgow, 1825) [James Bell on Physical Geography, 258–64, 305–10 and 409–13; James Bell on mathematics and the use of the globes, 299–304].
83. Livingstone, *op. cit.* (ref. 2, 1995), 29.
84. Quoted in Shapin, *op. cit.* (ref. 70), 154.
85. Frank M. Turner, "Public science in Britain, 1880–1919", *Isis*, lxxi (1980), 589–608, p. 591.
86. Steven Shapin, "Science and the public", in Robert C. Olby, Geoffrey N. Cantor, John R. R. Christie, and Martin J. S. Hodge (eds), *Companion to the history of modern science* (London, 1990),

990–1007; on this point and the 'shaping' of a particular public, see Daniel Goldstein, "'Yours for science': The Smithsonian Institution's correspondents and the shape of the scientific community in nineteenth-century America", *Isis*, lxxxv (1994), 573–99.

87. Habermas, *op. cit.* (ref. 9), 39.
88. On these issues of public space and the public sphere, and on attempts to reconstruct a geography of lecturing for Chartism, see Philip Howell, "Public space and the public sphere: Political theory and the historical geography of modernity", *Environment and planning D: Society and space*, xi (1993), 303–22; *idem*, "The aspiration towards universality in political theory and political geography", *Geoforum*, xxv (1994), 413–27; *idem*, "'Diffusing the light of liberty': The geography of political lecturing in the Chartist movement", *Journal of historical geography*, xxi (1995), 23–38; Miles Ogborn, *Spaces of modernity: London's geographies, 1680–1780* (New York, 1998).
89. Dena Goodman, "Introduction: The public and the nation", *Eighteenth-century studies*, xxix (1995), 1–2; Anthony La Vopa, "Conceiving a public: Ideas and society in eighteenth-century Europe", *Journal of modern history*, lxiv (1992), 79–116; Roy Porter, "The new eighteenth-century social history", in Jeremy Black (ed.), *Culture and society in Britain, 1660–1800* (Manchester, 1997), 29–50.
90. The issue of *Eighteenth-century studies* cited in ref. 89 has a strongly literary perspective on the public sphere: for two papers that do more than gesture towards the public sphere as geographically different, although only at the national scale, see Anthony J. La Vopa, "Herder's *Publikum*: Language, print, and sociability in eighteenth-century Germany", 5–24, and Kathleen Wilson, "Citizenship, empire, and modernity in the English provinces, *c.* 1720–1790", 69–96. Wilson takes her ideas further in her *Sense of the people: Politics, culture, and imperialism in England, 1715–1785* (Cambridge, 1995). For an overview of the public sphere as an issue suggestive of geographical differences, though the piece closely associates the public sphere with the Enlightenment, see Margaret Jacob, "The mental landscape of the public sphere: A European perspective", *Eighteenth-century studies*, xxviii (1994), 95–113.
91. Goodman, *op. cit.* (ref. 89), 4.
92. Eley, *op. cit.* (ref. 12), 296.

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THE NON-CORRELATION OF BIOMETRICS AND EUGENICS: RIVAL FORMS OF LABORATORY WORK IN KARL PEARSON'S CAREER AT UNIVERSITY COLLEGE LONDON, PART 1

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> I have great hesitation in taking any initiative at all in the Eugenic Records Office, because I did not want you to think that I was carrying all things into the biometric vortex!
>
> (Karl Pearson to Francis Galton, 1906)[1]

> The Drapers' Biometric Laboratory is the older, and had become a training school for mathematical statistics before Sir Francis Galton had thought of his Eugenics Laboratory.
>
> (Karl Pearson, 1918)[2]

Scholarship on the methods and techniques that the English biometrician and eugenicist, Karl Pearson (1857–1936), devised and deployed in two of his laboratories has been shaped by the underlying premise that there was one overall method and unifying approach in the Drapers' Biometric Laboratory and the Galton Eugenics Laboratory.[3] Virtually all historians of science have adopted this uni-dimensional and mono-causal historiographical premise in their work on Pearson. In this paper I shall undermine this premise and argue that there is a clear need to disaggregate the methods and tools in these two laboratories.

Whilst the origins of this debate on Pearson can be traced to 1911, it has been the debates from the 1970s, as exemplified in the works of Donald Mackenzie and Bernard Norton, in particular, that have received considerable attention from historians of science. Norton argued that Pearson's presumptively lifelong "methodological and ontological commitments" played an important role in science.[4] Mackenzie, trained in the Edinburgh School of the 1970s, claimed that the analysis of Pearson depends "on notions of class interests". He further argued that

> the biometric approach to [a statistical method to measure] association was the ... result of the needs of eugenics and [can] be seen as ultimately sustainable by professional middle class interests.[5]

Though people of Pearson's social class may have indeed been more amenable to eugenics, social class is not a strict functional determinant of belief. It will be shown that Pearson's development and construction of biometric methods (or the modern theory of mathematical statistics as Pearson defined his work) was a

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development entirely separate from the methods he devised in the Eugenics Laboratory. This paper will thus challenge the widely-held assumption that Pearson's statistical techniques for analysing biological variation were driven by his eugenic concerns.

Mackenzie and Norton were both brought up on a philosophical tradition which held that scientists had a unifying and consistent philosophical methodology throughout their entire life. Mackenzie argued that a scientist's social interests (arising from his social class) determined an individual's professional career whereas Norton borrowed his monolithic approach from philosophy and saw science as a rational activity. Both were influenced by the Ph.D. thesis of Lyndsay Farrall who claimed that "both Pearson and Galton looked to the methods of the biometric school as the suitable methods for the study of human evolution to which Galton had given the name eugenics";[6] thus implying that Galton and Pearson shared the same methods and commitments.

Subsequent historians such as Daniel Kevles, Theodore Porter and Richard Soloway have based their work on Pearson on Mackenzie and Norton, and they have adopted an historiographical perspective which I do not share.[7] As I have already argued elsewhere, no scientist should be expected to use one method only; indeed, a scientist may improve and adopt different methods for different situations.[8] Pearson did not have one overall approach governed by social class; his scientific work was not monolithic and is more complex than hitherto suggested. He had different agendas for various people and had many different personae in response to his diverse audiences; thus, a homogeneous approach cannot explain the many different activities that he undertook. There are other significant factors that help to explain the different kinds of work and the variety of research projects that were undertaken in his laboratories. Pearson was often engaged in different activities at the same time, such as lecturing to diverse audiences, assisting his students with their projects, editing his journals, writing his own papers and generally managing his laboratories.[9]

I will argue that individual actions are to a considerable degree shaped by their institutional setting, which may embody conflicting or incompatible interests in which individuals may pursue different interests at different times. Rather than assessing Pearson's work simply by looking at the final product in his published papers, as has typically been done by historians of science, the work undertaken by Pearson and the assistants in his laboratories will be examined to give a better idea of its immense diversity. Moreover, the work in the Eugenics Laboratory needs to be further explained and aspects of Pearson's work that have been taken for granted and labelled as though eugenics sums up everything about Pearson need to be 'unpacked'.

Insofar as historians have addressed Pearson's work in relation to his laboratories in the twentieth century, they have engendered the belief that his work in the nineteenth century played a minor role in the development of his statistics. When Gigerenzer, Swijtink, Porter, Datson and Beatty discussed this work they held that "the work of Karl Pearson and the biometric school could conveniently be dated to 1900, when Pearson published his chi-square test of 'goodness of fit'".[10] Historians who have been predisposed to see Pearson in philosophical or sociological terms only have tended to rely very heavily on his positivistic *Grammar of science* as a means of explaining his epistemology and work throughout his entire life. This book contains Pearson's first eight Gresham lectures delivered at Gresham College in the City of London in November 1891.[11] Though there were two further editions, the *Grammar* does not reveal everything about Pearson's thinking and ideas especially those in connection with his development of the modern theory of mathematical statistics. Thus, it is not helpful to see this particular book as an account of what Pearson was to do throughout the remaining 42 years of his working life.

Despite the many different and mutually irreducible strands of intellectual and practical activities that were undertaken in Pearson's laboratories, historians of science have completely failed to differentiate the forms of work going on in them. One of the earliest conflations of methods in the Biometric and Eugenics Laboratories occurred shortly after Pearson was appointed to the Galton Chair of Eugenics in 1911 (as Galton had so expressed in the codicil to his will), enabling Pearson to set up his Department of Applied Statistics. He took up his new post on the condition that University College London (UCL) would hire a permanent lecturer to undertake the teaching of undergraduates in the Department of Applied Mathematics and would also supplement the Galton Laboratory by about £300 annually.[12] At this time other departments at UCL felt that Galton's endowment provided adequately for all of the needs of the Department of Applied Statistics, and consequently believed that Pearson should not receive additional money either from UCL or from the Drapers' Company. Pearson, however, argued that this was "very far from the case and [was] due to a misunderstanding of the relation of the two laboratories".[13] He explained that

> it is well known to the University Authorities that Galton established first a fellowship in the science of Eugenics and a Eugenics Record Office. With this I had practically nothing whatever to do. Galton supervised this office himself, and my only relation to it was that its members used to come in occasionally to the Biometric Laboratory for friendly consultation and advice.[14]

The laboratories thus did not merge and remained separate institutions which relied on funding from different sources. Pearson further explained that "the association of the two laboratories therefore arose from the fact that the Drapers' Biometric Laboratory appeared to be the only school at that time producing the type of work that Galton thought was necessary to carry on research in eugenics".[15]

Nevertheless, this association has been a predominant feature in the historiography of Pearson's work, and historians of science have not only overemphasized his work in eugenics, but have linked the statistical methodology that Pearson devised in the Biometric Laboratory to the methods that he used in the Eugenics Laboratory. When C. P. Blacker examined Galton's methods for eugenics in 1952, he thought that Pearson considered "biometry which includes anthropometry and psychometry [to have formed] the scientific basis of eugenics".[16] Whilst Pearson remarked that "the science of eugenics is in fact only highly developed and *applied* anthropology [which would] demand of the student intensive preliminary training in mathematical statistics, anthropology and general genetics", he also argued that "the study of eugenics centre[d] around the actuarial treatment of human societies in all of its phases, healthy and morbid".[17] Pearson did not use the term 'biometry' to describe his methods in the Eugenics Laboratory nor did he imply that biometry formed the "scientific basis of eugenics".

Writing some fifteen years later, Victor Hilts rather astutely argued that "Pearson's belief in the extension of [eugenics] did not arise originally from the development of mathematical statistics".[18] However, he also claimed that "statistics and eugenics became united in [Pearson's] own mind" and that "it was in 'eugenics' that statistics was to be associated with a new science of man itself".[19] Three years later when Lyndsay Farrall examined the two laboratories, he claimed that

> the real bond between the two laboratories was the techniques of research used rather than the subject matter of research. In both laboratories the basic technique of research was the statistical analysis of large masses of observations on collected data.[20]

Though it may be said that the basic *approach* (rather than "technique") involved the analysis of "large masses of observation" in both laboratories, this view overlooks the complexity of the different methods developed in the two laboratories. Farrall then argued that as the "biometric laboratory was already carrying out the work that Pearson felt was important research in eugenics, it was also quite natural that two laboratories of which he was director should come to be seen by him as part of one institution".[21] Yet Pearson explained in 1918 that the Galton

> Eugenics Laboratory ... did not replace the Drapers' Biometric Laboratory which simply provided for it such excellent research workers as Miss Ethel Elderton and Dr [David] Heron. Their work was confined to a relatively narrow field, having nothing to do with statistical theory or its general application to biology.[22]

Donald Mackenzie, Bernard Norton, and Theodore Porter subsequently reached the same conclusion as Farrall. Norton argued in 1978 that "certainly in Pearson's time statistics was always associated with eugenics".[23] However, this perspective has taken into consideration neither (1) the full range of statistical methods used in Pearson's time such as vital statistics, economic statistics, mechanical statistics, geometric statistics or government statistics, as well as the bulk of Pearson's statistical methods used in the Biometric Laboratory, that had no association with eugenics, nor (2) those methods used in the Eugenics Laboratory which were not "statistical". Mackenzie maintained that "to separate a 'neutral' biometry from 'ideological' eugenics would be ahistorical and would fail to capture the integral notion of Pearson's thought".[24] He thus thought that "the needs of eugenics figured large in

[Pearson's] work in statistical theory".[25] When he examined the methods used in both of Pearson's laboratories, he claimed that in Pearson's

> last report to the Worshipful Company of Drapers, Pearson warned of the need to keep statistical theory "in touch with practical needs" ... and there is no doubt that in his mind eugenics was the source of the most central of these practical needs. In reality, there seems to have been little clear demarcation between the Biometric and Eugenics Laboratories, which shared personnel, methods and problems. The Laboratories are best seen as a unified research institute pursuing, at least in the period up to 1914, a multi-faceted but still integrated research programme.[26]

Daniel Kevles, who shared Mackenzie's view, maintained that

> roughly speaking, the statistical techniques for dealing with the data were developed in the Biometric Laboratory, and the analysis was carried out in its Galton counterpart, but the symbiosis was so close as to make the distinction meaningless. [27]

Theodore Porter, who used much of Mackenzie's work, maintained that "Pearson's eugenic conviction provided the principal explanation for the enthusiasm with which he took up the study of statistics".[28] A number of other historians with interests in Pearsonian statistics have subsequently repeated these views. Rosaleen Love, for example, claimed that Pearson "founded the Biometric Laboratory in order to collect statistics relating to eugenics" and Judith Walkowitz thought that Galton's *Natural inheritance* "converted [Pearson] to eugenics, the statistical study of human manipulation".[29] Gigerenzer *et al.* held that it was worth considering

> the extent to which the biometricians and Mendelians were involved in eugenic research and eugenics propagandizing. Indeed the biometric and Mendelian schools were the academic/intellectual *foci* of eugenical discussions during the last part of the nineteenth century and the first part of this century.[30]

Richard Soloway argued that the link between Pearsonian statistics and eugenics occurred

> even before [Pearson] turned his considerable mathematical talents to the cause of Galtonian eugenics in the early 1890's. Pearson called for careful evaluation of gender capacity and ability and tried to formulate accurate statistical procedures for measuring the hereditary contribution of each sex.[31]

Hence, historians have tended to gloss over crucial differences in the techniques and the methodologies in the two laboratories. This historiographical tendency to link *in toto* Pearson's work in the Galton Eugenics Laboratory to his work in the Drapers' Biometric Laboratory is, without doubt, the most problematic aspect in the historiography of Pearsonian statistics. Moreover, the general historiographical trend has been to over-emphasize Pearson's work on correlation and regression to the neglect of all other statistical methods, techniques, tools and instruments that played a central role in the many different projects that he undertook in both laboratories. This paper will thus show how this false conflation of the work in Pearson's laboratories and how the excessive emphasis on the importance of eugenics in Pearson's work by historians have seriously distorted an overall understanding.

The principal methodology in the Drapers' Biometric Laboratory was underpinned firstly by Pearson's seminal statistical work on curve-fitting and goodness of fit testing for distributions of various shapes, and secondly by a series of correlational methods and statistical regression along with matrix algebra. The methodology in Pearson's Eugenics Laboratory by contrast involved the use of family pedigrees and actuarial death rates. Pearson's approach in the development and deployment of the principal methods in the two laboratories differed in a number of ways. His biometric methods were used for the *analysis* of data and were generalizable; moreover, they were innovative, sophisticated and rigorous. In contrast, the pedigrees in the Eugenics Laboratory were used initially by Galton, served as a tool for *collecting* data, and were not generalizable. Though this method was not statistically rigorous, the pedigrees were, nonetheless, visually impressive. This latter approach may have also reflected Pearson's ambivalence towards this enterprise. Additionally, Pearson's work on heredity needs to be given careful consideration. Whilst some of his work on heredity was undertaken in the Eugenics Laboratory, a very substantial amount of his projects on heredity was pursued in the Biometric Laboratory. Thus not all of the problems on heredity for Pearson can be associated with eugenics.

Whilst the methods in the laboratories varied greatly, the personnel (including the workers, students and assistants), funding and the types of articles printed in the organs of both laboratories were also of distinct entities. The Biometric Laboratory, in particular, relied on dozens of voluntary workers as well as human computers, calculators and a computator. Whilst Farrall and Mackenzie have argued that the funds of the biometric laboratory were derived from links between statistics and eugenics, Pearson, however, ensured that the funding and the finances for both laboratories were kept separate and, in fact, he kept separate bank accounts for each laboratory.[32] In a period of 28 years Pearson founded and edited seven journals for the dissemination of that work. *Biometrika* (of which he was a co-founder with Weldon and Galton), the *Drapers' Company research memoirs: Biometric series*, and the *Drapers' Company research memoirs: Technical series* were the organs of the Biometric Laboratory. The work in the Eugenics Laboratory was published in the *Eugenics Laboratory lecture series*, the *Drapers' Company research memoirs: Studies in national deterioration*, *Treasury of human inheritance*, and the *Annals of eugenics*. Both sets of journals had distinct methodological styles.

During the first three decades of the twentieth century, Pearson established and ran four laboratories. His first laboratory was the Drapers' Biometric Laboratory: it was in this laboratory that he carried out most of his own work and from which 406 (or 63%) of his publications emanated. The Astronomical Laboratory and the

FIG. 1. University College, *c*. 1906.

Anthropometric Laboratory were subsidiary to the Biometric Laboratory. All three, to some degree, shared the same building space. Whilst Pearson taught astronomy in the same building where he first taught applied mathematics in 1884 and then biometrics in 1893, he also set up two student observatories in 1904 which occupied a different physical space. By the time he had set up the Anthropometric Laboratory in 1922 he was no longer running the Astronomical Laboratory, and by then he had finally had one building to house all of his laboratories. From 1907 till 1922, the Eugenics Laboratory was situated in two rooms on Gower Street. From the work Pearson and his assistants undertook in this laboratory, he published 49 papers (or less than 1% of the total number of his publications).

The Drapers' Biometric Laboratory grew out of the Biometric School which had its earliest beginnings at Gresham College in 1892 and its more formal beginnings at University College London in 1893. (The main building with the rotunda and portico in Figure 1 is the site where Pearson first taught applied mathematics and mechanics from 1884 to 1911, and where the Biometric Laboratory was situated from 1903 to 1922.) The laboratory was set up in 1903 following a grant from the Worshipful Company of Drapers, which funded Pearson annually until his retirement in 1933. The bulk of the original Drapers' grant enabled Pearson to supply the statistical section with such instruments as calculating machines and integrators, to hire a permanent computator and another assistant and to pay for the printing and publication of original work. The general aim of the expenditure was to "maintain a statistical school for post-graduate work".[33] Under Pearson's direction, the Drapers' Biometric Laboratory was to provide "a complete training in modern statistical methods" and was especially arranged so as to "assist research workers engaged on biometric problems".[34] Of the four laboratories, this one had the greatest number of workers (known as the biometricians) and had an international reputation which the other laboratories never quite acquired.

A year after Pearson had established the Biometric Laboratory, the Drapers' Company gave him a grant so that he could establish an Astronomical Laboratory equipped with a transit circle and a four-inch equatorial refractor.[35] Two student observatories, the Drapers' Company Transit House and the Equatorial House, were erected on the South Lawn of UCL and were used for teaching practical astronomy at University College. (Both of these observatories may be seen in the foreground of Figure 1.) The purpose of the observatories was not *direct* research work, which was largely impossible inside a big city, but to show the students the practical aspect of astronomy and interest them in astronomical research work.[36] The observatories were also equipped with a 6-inch equatorial telescope with photographic and spectroscopic accessories. John Blakeman was Pearson's principal computer in this laboratory. One of Pearson's primary interests lay in determining the correlations of stellar rotations and the variability of stellar parallax. He set up an astronomy degree course at UCL in 1914.

Several months after Pearson established his Astronomical Laboratory, Francis Galton (1822–1911) established The Eugenics Record Office when he gave the University of London £1,000 for "the furtherance during three years of the scientific study of eugenics".[37] The Office was set up in two rooms at 50 Gower Street and the staff consisted of Edgar Schuster as Research Fellow and Ethel Elderton as his assistant.[38] Galton supervised this office himself. Pearson's role was minimal: he was not on the Advisory Committee for the Eugenics Record Office nor had Galton "ever consulted [him] ... as to the research in his office".[39] From time to time Pearson would mention to Galton that his experience in the Biometric Laboratory taught him the serious length of time it took to collect statistical data and then to reduce them fully by his modern statistical methods. Galton, however, wanted to show immediate results and it was this difference in their methodological approaches that caused Pearson to "[stand] as far as possible aloof from it, except when Galton or his assistant [Edgar Schuster] directly consulted [him] on a statistical point".[40]

Two years later, in 1906, Schuster retired as he wanted to undertake more purely biological work. Surprised at Schuster's resignation, Galton wrote to Pearson on 24 October as he wished that the Eugenics Record Office could "somehow be worked into your biometric laboratory, but I am far too ignorant of the conditions to make a proposal.... If any feasible plan occurs to you, pray tell me".[41] An agreement for Pearson's take-over was made by the end of the year. Thus, the Galton Eugenics Laboratory (as renamed by Pearson) was established on 1 February 1907 under Pearson's direction, in two small rooms at 50 and 85 Gower Street. Galton provided £500 a year during his lifetime and left the residue of his estate of £30,000 to UCL in 1911.[42] The Laboratory carried on Galton's aim of determining "those causes under social control that may improve or impair the racial qualities either physically or mentally".[43] Nevertheless, Pearson was very reluctant to take over the Eugenics Laboratory. If anything, eugenics was a source of tension for him. From the beginning, he recognized that the statistical methods he devised and the instruments he used in the Drapers' Biometric Laboratory were not adequate to answer some of Galton's questions on matters relating to eugenics. Pearson then devised a completely different methodology.

In 1922, with the financial backing of his student, Ethel Elderton, Pearson set up an Anthropometric Laboratory, his fourth laboratory, with the intention of collecting physical, mental and psychological data from as many male and female UCL students as was possible. They tested sight, hearing, judgement, mental agility and strength, and had recommended some students to consult ophthalmologists. The statistical tools he used in his Astronomical and the Anthropometric Laboratories were borrowed from those that had been devised in the Biometric Laboratory. Various methods of correlation were, for example, used for work undertaken in the Astronomical Laboratory and the standard deviation, mean and coefficient of variation were used in the Anthropometric Laboratory.

THE CREATION OF A STATISTICAL AND BIOMETRIC LABORATORY

Academics in the nineteenth century were employed to teach, and thus their laboratories had to fit into their teaching requirements.[44] When Pearson first took up his post as Goldsmid Professor of Applied Mathematics and Mechanics in 1884, he lectured single-handedly 11 hours weekly. His teaching was divided into two sections — those for degree students and those for engineering students. For engineering students, the emphasis was on "geometrical and graphical procedures [since these students] usually had not a great belief in theoretical training". His chief assistant in the department, Ebenezer Cunningham (who graduated with honours from Cambridge in 1903, being a Senior Wrangler and a First Smith's Prizeman), taught some of the undergraduates, and with his assistance Pearson doubled the time he spent in his research laboratories.[45] Pearson had not experienced difficulty in maintaining order nor in gaining the interest of this rather large section of students. In addition to classes in statics, dynamics and general mechanics, he gave courses in mathematical physics, sound, electricity, light, electricity and magnetism, wave-motion and hydrodynamics.[46]

Although no laboratory had been at his disposal nor had any instruments or apparatus been at the service of the department, he had always endeavoured to keep in touch with the physical side of the mathematics. By 1897 he was lecturing 16 hours weekly and was responsible for co-ordinating 20 additional hours weekly with assistance from two demonstrators and from George Udny Yule (1871–1951), who had been made Assistant Professor in 1896.[47] He was able to set up a well-equipped calculating and integrating room with a collection of instruments that was increasing

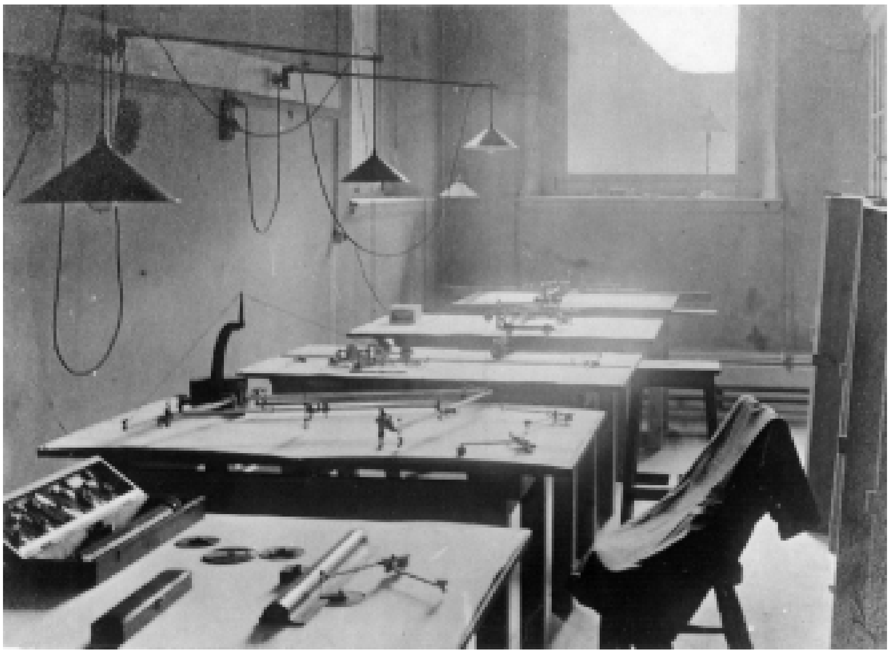

FIG. 2. Pearson's instrument room at University College.

annually.[48] The instrument room, where the biometricians would have used curve-plotters, integrators and calculating machines, is shown in Figure 2.

The number of students in Pearson's Biometric School grew from about four students in 1893 to nearly 20 at the end of the century. Virtually all of the computing work was, however, "entirely done by volunteer workers".[49] Hence, Pearson could never depend upon permanent computers, and his investigations were extended over a number of years owing to his workers being called off to other employment. He first conceived of a Statistical Laboratory in 1900, which occupied then "a slip of a room with inadequate lighting".

In March 1903 the Worshipful Company of Drapers announced their intention of granting £1000 to the University of London to be devoted to the furtherance of research of higher work at UCL. After consultation between the university and college authorities, the Drapers' Company presented £1000 to the University to assist the statistical work and higher teaching of the Department of Applied Mathematics which was "probably [the] first occasion on which a great City Company ha[d] directly endowed higher research work in mathematical science".[50] When the Drapers' Biometric Laboratory opened weeks later, it was the first mathematical laboratory in Britain.[51] By then, Pearson had already developed and formulated the fundamental corpus of his statistical theory.

The Drapers' grant enabled Pearson to shift a certain amount of teaching work onto the shoulders of competent assistants, and provided him with two permanent assistants: Dr Alice Lee (the first woman to have received a D.Sc. in the University of London) was his highly qualified chief computator and John Blakeman was responsible for measurement and microscopic work. Additional computers included two Senior Cambridge Wranglers from Trinity College, a Mr Clerk Maxwell Garnet and a Mr W. F. Everitt. Pearson had chosen Cambridge Wranglers since "these men [were] not only able to give assistance to those working in the department, to revise for press mathematical and other memoirs, but to solve mathematical problems arising in the course of the statistical research in the Biometric Laboratory".[52] He was also able to hire by occasional payment Miss F. Cave of Girton College, Cambridge as an additional calculator. Like Pearson, a number of people who worked for him were also of Cambridge calibre. Thus, for Pearson, institutional pedigree mattered considerably whereas gender, *per se*, did not seem to be as important.

The money Pearson received from the Drapers' Grant was also used to purchase a Leitzmicroscope (at £29) for making fine measurements and a very good reading microscope (£26). The microscopes were particularly valuable to their biometric work because previously they had to either borrow a microscope from another department or apply to the Royal Society for the loan of one.[53] He was thus also able to pay two other microscopists who worked on specific projects: Miss Marion Radford worked on the inheritance of snails and also took measurements on a series of human teeth to compare to prehistoric Egyptians of 8000 B.C. and Miss Alexandra Wright did microscopic work on the variability of drones, queens and worker wasps (*Vespa vulgaris).* Wright had made between eleven and twelve thousand microscopic measurements and the indices and all statistical reductions were carried out by Alice Lee.[54] A second study was followed up two years later by Eveline Thomson, Julia Bell and Pearson.[55] Julia Bell, who worked for Pearson from 1908 to 1933, was paid by the Government Committee for Medical Research. A year after they completed the second study, the Oxford economist and statistician, Francis Ysidro Edgeworth, wrote a paper on the statistical observations of wasps and bees.[56]

In addition to this work the biometricians were also involved in very extensive calculations and computations for a series of tables for mathematical statistics.[57] One of Pearson's objectives when he helped to establish the journal *Biometrika* was the provision of a set of numerical tables which would "reduce the labour of statistical arithmetic". During the next twelve years a series of tables, most of which Pearson had planned, appeared in *Biometrika* and in 1914 he issued a separate volume for *Tables of statisticians and biometricians*.[58] This volume of tables had taken its place as a standard book of reference for human computers and statisticians.

The purpose of these tables of mathematical statistics was to enable the table-user to draw conclusions from observational data in terms of probabilities. Such standard tables of probability included a table for the normal distribution (to determine, for example, the ordinate of the area under the normal curve), the chi-square table, Student's t-table and the square-root table. Other tables included those for incomplete gamma and beta functions.[59] The computations of tables of mathematical statistics continued during the whole of Pearson's time as Director of the Biometric Laboratory. The Drapers' grant enabled the computers to be employed for long years in the preparation of these tables.

Biometric "Investigations" in the Field

In the summer of 1899 Pearson started a "biometric camp" at Peppard in the Chilterns to investigate biometric problems. A number of these investigations were concerned with inheritance in a variety of plants. Pearson was interested in pursuing his theory of homotyposis which he defined as "the quantitative degree of resemblance to be found on the average between the like parts of organisms".[60] One of their first projects involved the study of homotyposis in the Shirley poppy; this project was on a larger scale than any of their previous studies and there were eight biometricians working daily.[61] Weldon gave Pearson the "criticism, suggestions and encouragement, in which he never failed".[62] Whilst the collection of poppies began at Hampden Farm in Buckinghamshire, they also collected data from Lyme Regis in Dorsetshire, Monmouthshire, Somersetshire, as well as from different parts of London including Hampstead (near Pearson's home), Dorking, St Albans and Haslemere. They dealt with more than one thousand plants and counted the bands from more than ten thousand capsules. The collection and reduction of the data took nearly a year to complete.[63]

From this summer work arose the Friday "biometric teas" where plans would be made to discuss the work for Saturday and Sunday which were "given to calculating and reducing weekly work". By then Weldon had moved to Oxford and he took a weekend cottage to be nearby. Various biometricians from the Biometric Laboratory and another contingent from Oxford joined in the activities. Galton was usually there when the biometricians carried out their investigations in the London area.

In addition to the work on homotyposis in the plant and animal kingdom, as well as the cooperative studies on wasps, the biometricians were also interested in problems of physical anthropology in prehistoric races. This work involved a very considerable amount of craniometric and osteometric measurements which continued well into the twentieth century. Weldon and his students at Oxford undertook a series of investigations in an attempt to detect empirical evidence of natural selection.[64] Weldon's research work on *Clausilia Laminata* (Montagu), published in 1902, has been considered to be some of his most convincing work in demonstrating empirical evidence of natural selection.[65] He found that the species of *Clausilia Laminata* (Montagu) showed possibly "more clearly than other species, the way in which small and apparently unimportant differences of structure [in the whorls in the snail] are associated with the difference between the survival and the total extinctions of a race of a particular locality".[66]

By the end of the nineteenth century, Pearson had not only established methods to measure linear relationships for continuous variables (including simple correlation and simple regression, multiple and partial correlation and multiple regression), but he began to devise a variety of methods to measure relationships for discrete variables such as the phi-coefficient and the tetrachoric correlation.[67] Some of the most commonly used continuous variables for the biometricians included stature, length and breadth; some examples of their discrete variables included eye-colour, hair colour, and coat colour in animals. In the early years of the twentieth century, the biometricians were interested in determining the relationship between Galton's law of ancestral heredity and Mendelian genetics.

From 1903 to 1918 there were 62 research workers who had spent some time in the Biometric Laboratory. The list of people who assisted in this laboratory "could be considerably extended by numerous schoolmasters and mistresses who worked in the laboratory" for various lengths of time.[68] The total number of memoirs and papers published by those working in the Drapers' Biometric Laboratory was 297, and 62 of his students had published articles in *Biometrika*.[69] In 1909 the laboratory had developed into two large rooms capable of providing for twelve or more post-graduate students.[70] By then, his work and his School had achieved international recognition, with students coming from America, France, Germany, Italy, India, Japan, Russia and Sweden to learn Pearson's biometrical methods. Students who lived in Britain came from Oxford, Cambridge and the Scottish universities.

Pearson's investigations of heredity were so extensive that various aspects of this work were undertaken in both laboratories. When the following three problems occurred the work was undertaken in the Biometric Laboratory: (1) investigations on the inheritance of characters in plants and animals (whether it was homotyposis, Galton's law of ancestral heredity or Mendelian genetics), which involved a substantial amount of field work, calculations and microscopic work; (2) the examination of such continuous variables as stature/breadth/length in plants, animals and humans, for which they used various measures of correlation for continuous variables (such as the product-moment correlation coefficient, multiple and partial correlation) and other suitable biometric methods (including the standard deviation and the coefficient of variation); and (3) the analysis of such discrete variables as eye-colour and coat colour in animals as well as eye-colour and hair colour in humans, for which Pearson used his tetrachoric correlation and phi-coefficient in 1899 and he began to use his chi-square test of association for contingency tables in 1904. When Pearson began to examine the inheritance of so-called defective, diseased or dysgenic characters (such as mental deficiency, TB and alcoholism), this work was undertaken in the Eugenics Laboratory using different sets of tools and methods. By the same token, such eugenic characters as musical ability were also investigated in the Eugenics Laboratory. This work would have fulfilled Galton's aims for the laboratory.

The methodology incorporated in the Drapers' Biometric Laboratory was two-fold: the first was mathematical and included the use of Pearsonian statistical methods (which sometimes required the use of matrix algebra) and analytical solid geometry; the second involved the use of such instruments as integrators, analysers and curve plotters plus the cranial coordinatograph, silhouettes, and cameras.[71] The underlying statistical procedure used in the Drapers' Biometric Laboratory, particularly by Pearson, involved curve-fitting and goodness of fit testing. The chi-square (χ^2, P) goodness of fit test was used when the theoretical distribution was (1) known *a priori*, such as already established sets of data from the General Registrar Office or Hospital records on mortality; (2) not known *a priori* and, therefore, the theoretical distribution would need to be calculated by determining the probabilities of the empirical distribution; and (3) when fitting the Poisson distribution and (much later in Pearson's time) the Normal distribution.[72] This test would remain paramount in Pearson's statistical work throughout the rest of his life. His work on goodness of fit testing stimulated a number of his students to bring about further theoretical developments in curve-fitting.[73] In 1933, three of his students wrote articles which involved finding a better fit for a hypergeometric distribution, non-normal symmetric distributions and re-examining the idea that the starting point of a distribution for curve-fitting is fixed at zero.[74]

Pearsonian correlational methods and regression were perhaps the second most frequently used set of techniques in the Biometric Laboratory (in addition to Pearson's standard deviation and his coefficient of variation). By 1918, he had devised seventeen different correlational methods which had been used in a number of articles in *Biometrika*. The various methods were created in response to a number of considerations: the scale of measurement of the variables, the number of variables to be analysed, and the types of questions asked by the researchers. For scale of measurement Pearson made distinctions between those variables which were "discrete" and those that were "continuous". Variables are discrete when they cannot be measured and can only be counted, whereas continuous variables, such as weight, stature and breadth, can be measured, usually by an instrument (such as scales, rulers and callipers). In 1899 Pearson made sub-classifications of discrete variables when he designated some variables as "nominal" which required "naming" the characteristics of a variable (such as brown, blue or green for colour of eyes), and other variables were classified as "ordinal" when the characteristics are ordered on a scale (such as Pearson's scheme of colours for eye-colours where the darkest colour "black" to the lightest colour "light blue"); the same scheme was used for coat colour of animals where he used the seventeen categories classified in Wetherby's studbook.[75] Pearson also created a category for variables that were dichotomous (i.e., when only two outcomes could be ascertained) and this was subdivided into "true" dichotomies and "artificial" dichotomies. (See Table 1 for definitions and examples used by Pearson for these scales of measurement.)

Some of the more commonly used methods of correlation are the following: the product-moment (or simple) correlation (r), partial ($r_{0p.q}$) and multiple correlation (R), the phi-coefficient (ϕ), tetrachoric correlation (r_t), biserial correlation (r_b), variate difference method ($r_{x\,y}$) as well as the chi-square test of association (χ^2), the contingency coefficient (C) and the correlation ratio (η).[76] Their work on craniometry and

TABLE 1. Pearson's Scales of Measurement. This involves the assignment of numbers to variables according to the following rules:

Types of Scales General: Specific	Definitions	Biometric Examples Used by Pearson
Continuous[1] (1893)	Though Pearson used continuous variables exclusively from 1892 to 1899, he did not refer to this as a scale of measurement until 1899. Reference was made to the normal distribution which assumes continuous data and he also referred to 'continuous curves'. The objects here are assigned numbers so that equal differences (or equal 'intervals') between the numbers assigned to the objects reflect equal differences.	-Height/stature -Breadth and length -Age -Temperature readings on a Fahrenheit or Celsius scale
Discrete: Nominal[2] (1898)	This involves simply counting or naming the categories. All objects must be placed into mutually exclusive and exhaustive categories. Most demographic variables fall into this category.	-Sex: male/female -Eye-colour: blue/green/brown
Ordinal (1898)	In addition to naming the categories, the classification of variables are ordered on a scale where one category must follow another or be above another category. Nothing is implied about the size of the category.	-Pearson's classification of colours: here the intensity of shades was ordered in 8 categories from the darkest (black) to the lightest (light blue)
Dichotomous (1898)	This is used for categories with two outcomes only and is quite often used to measure the absence or presence of something. Pearson also differentiated between 'true' and 'artificial' dichotomies. 'True dichotomy' occurs when the variable is truly discrete with only two outcomes. 'Artificial dichotomy': These variables quite often fall originally on a continuous scale and thus the cut-off point is arbitrary.	-Whetherby's studbook of 17 categories of colour of thoroughbred horses True dichotomy: vaccinated/not vaccinated; dominant and recessive Mendelian alleles; tall/short; green/yellow Artificial dichotomy: height is typically measured on a continuous scale; when it is classified as 'short' and 'tall', the dichotomy is artificially created

1. Pearson did not make any sub-classifications for continuous variables. In 1953, William Stevenson introduced a sub-classification for a continuous scale of measurement which was divided into 'interval' and 'ratio' scales. For an interval scale, the zero point is arbitrary and does not reflect the absence of an attribute (such as Celsius and Fahrenheit readings). For 'ratio' an absolute zero point exists on the scale and a measurement of zero indicates the absence of the property measure (such as height and weight). Most of the continuous variables that Pearson and the biometricians examined would have been ratio rather than interval.

2. The date refers to the year that Pearson worked out this scale; the paper was published in the following year.

physical anthropology led to the development of new procedures for analysing skulls and bones; the one statistical method Pearson devised for this purpose was the coefficient of racial likeness (C.R.L.) in 1921.[77] Thus, Pearson's work on curve-fitting, goodness of fit tests and correlation as well as such techniques as the standard deviation and the coefficient of variation, formed the core statistical methods that he and the biometricians used in the Biometric Laboratory. In addition to these

TABLE. 2. Descriptive or summary statistics used or devised by Pearson.

Measures of central tendency. These deal with the tendency of observations to centre around a particular score and the various measures used imply different definition of a 'central' score:

(i) Mean: the average score found by summing all scores and dividing by the number of scores summed.
(ii) Median: the 50th percentile in a group of scores such that half of the scores are larger than the median and the other half are smaller than the median. Galton introduced the median with his quartile measures in 1875.
(iii) Mode: the score in a set of scores that occurs most frequently; Person helped to popularize this measure.

Measures of variability. These measure the amount of dispersion, the scattering of scores, or the variability of a set of scores:

(i) Standard deviation: devised by Pearson in 1892, this measures the extent to which the observed values deviate from the mean value (i.e., how far from, or how close to, the mean are the scores).

(ii) Coefficient of variation: introduced by Pearson in 1896 to measure the standard deviation of a distribution divided by its arithmetic mean and then multiplied by 100; used to compare the variability of frequency distributions when making comparisons in the stature of men and women.

statistical methods, Pearson also adopted and developed various types of instruments in this laboratory. (See Tables 2–4, which list and define the most commonly used statistical methods devised and deployed by Pearson in the Drapers' Biometric Laboratory.)

Craniometry and Physical Anthropology

Sometime in 1895, Pearson had sent out some letters of enquiry in his search for "about 100 skulls of a homogeneous race".[78] The Egyptologist, William Flinders Petrie (1853–1942), responded to Pearson's request and let him examine his newly discovered Egyptian race of 103 skulls of the adult male crania from "the general population who occupied the district near Naganda in Upper Egypt some 5000 years ago".[79] Pearson considered this to have been the "finest anthropological collection — skeletons as well as crania — known to [him]".[80] Pearson's elder brother, Arthur Beilby Pearson-Gee (1855–96), had not only provided the funds for the collection, but he also packed and brought back the collection to England.[81]

In the late nineteenth century, the biometricians' ideas of inheritance centred around determining the extent to which stature could be found to be correlated in offspring and parents (or with collateral relatives). The emphasis would change in the twentieth century when they began to measure skulls with callipers by using the cephalic index B/L (Breadth divided by Length). They decided that cephalic index measurements, when used to test any theory of heredity, possessed two merits. Firstly, it was said that the "cephalic index remained sensibly constant after two years of age"; thus the strength of inheritance could be ascertained by measurements on young children whose parents were still alive. Secondly, they thought this could have been "a marked racial character [which] might be considered to be strongly inherited".[82] Rather than focusing on stature as the primary means to measure inheritance, Cicely Fawcett, Alice Lee and Karl Pearson were suggesting that the measurement of the cephalic index might shed light on problems of inheritance. The view that the skull "remained sensibly constant" (whereas stature is more

TABLE 3. Pearson's family of curves and the chi-square goodness of fit test. In 1895 Pearson produced a family of theoretical curves to interpret his distributions of data; he also devised various goodness of fit tests including, in 1900, his chi-square goodness of fit test, perhaps his single most important contribution to the modern theory of mathematical statistics.

Type I: Limited range in both directions and skewness (Asymmetric Beta Density Curve)
Type II: Limited range and symmetry (Symmetric Beta Density Curve)
Type III: Limited range in one direction only and skewness (Gamma Curve and Chi-square distribution)
Type IV: Unlimited range in both directions and skewness (Family of Asymmetric Curves and Student's t-distribution)
Type V: Unlimited range in both directions and symmetry (Normal Curve)
(In the first (1901) supplement to his family of curves he defined Types VI and VII, and then Types VIII and IX in his second (1914) supplement.)
The chi-square goodness of fit test: The test was constructed to compare observed frequencies in an empirical distribution with expected frequencies in a theoretical distribution, to determine "whether a reasonable graduation had been achieved" (i.e., one with an acceptable probability). The test provides a criterion to determine if there is a statistically significant difference between these two distributions.

variable) not only seems to have engendered the development of craniometry in the biometric laboratory, but it probably was pivotal in the later development of Pearsonian physical anthropology.[83]

There was a range of instruments developed and utilized in the Biometric Laboratory to obtain craniometric measurements. They included

> an osteometer of Broca type, an osteometer of Hepburn's model lent by Professor Thane, callipers of various types, a modified Klaatsch cranial contour tracer used for projecting various points of the bone onto a horizontal plane, a torsiometer of [their] own design, a whole plate of photographic camera with Goerz astigmatic lens used for obtaining an image of the head of the bone on a ground-glass drawing plate in the focal plane, a powerful electric lantern for illuminating the bone, and a solid stand with a universal joint for supporting the bone in any position, such as in general use in any physical or chemical laboratory.[84]

One of Weldon's colleagues, Herbert Thompson, had made a series of measurements on 301 male and female skulls.[85] In an attempt to find a measure of the "constancy of race" (as had been suggested by Weldon in 1890 when he used Galton's method of correlation for his work on the common shrimp), Pearson had taken Thompson's measurements and compared them to Professor J. Ranke's measurements in the *Beinhaüser* of the Bavarian churchyards of 900 modern Bavarian peasant skulls and also with Paul Broca's skull measurements of Parisians.[86] Pearson found the correlation between length and breadth of skull, the coefficient of variation for length and breadth of skull, and a measure of the cephalic index for each group. Instead of using standard deviations to determine the amount of variation in the different groups, he found when he used his *coefficient of variation* that

> the breadth of skull [was] in all cases a sensibly more variable quantity than length and ... possibly that the more civilised races are more variable. Both of these results have, I believe, very important bearing on the mathematico-statistical theory of evolution. [87]

TABLE 4. Pearson's most commonly used methods of correlation.

Methods	Year[1]	Symbol	Scale of Measurement[2]	Number of Variables	Measures	Range of Values
1. Product-moment correlation coefficient or Simple Correlation[3]	1895	r	Both variables are continuous	2	Linear relationship	−1 to +1
2. Multiple Correlation[4]	1895	R	All variables are continuous	More than 2	Linear relationship	−1 to +1
3. Partial Correlation	1895	$r_{0p.q}$	All variables are continuous	More than 2	Linear relationship	−1 to +1
4. Phi-Coefficient	1899	ϕ	Both variables are 'true' dichotomies[5]	2	Association	−1 to +1
5. Tetrachoric Correlation	1899	r_t	Both variables are 'artificial' dichotomies	2	Association	−1 to +1
6. Chi-square test of association for contingency tables	1904	χ^2	All variables are discrete	2 or more	Association	0 to ∞
7. Contingency Coefficient	1904	C	All variables are discrete	2 or more	Association	0 to almost 1
8. Correlation Ratio	1905	η	Both variables are continuous	2	Curvilinear relationship	0 to +1
9. Variate Differences method	1907	$r_{x\,y}$	Both variables are ranks (usually obtained from an ordinal scale)	2	Linear relationship	−1 to +1
10. Biserial Correlation	1909	r_b	One variable is continuous and the other is an artificial dichotomy[1]	2	Linear relationship	−1 to +1

1. For the first five methods the dates refer to the year that Pearson devised the method; the date of publication is in the following year. The last five methods were devised and published in the same years.
2. See Table 1 for definitions and examples of scales of measurement.
3. *Simple Correlation* measures the linear prediction between two variables of which one is the 'dependent' variable and the other is the 'independent' variables.
4. *Multiple Correlation* uses a collection of variables to measure the linear prediction between one 'dependent' variable and two or more 'independent' variables.
5. See Table 1 for definitions and examples of true and artificial dichotomies.

The arithmetic involved was of such a very lengthy and laborious character that Pearson "would have hardly as got as far as it has already done, had it not been for the hearty assistance of [his] very zealous helpers, Miss Alice Lee and Mr. G. U. Yule".[88] This research was, however, set aside for ten years and they did not begin to work on it again until 1907 (a year after Weldon's death). Work continued on this subject until the outbreak of the First World War. A year after the war had ended, and 22 years after Pearson and the biometricians first began this project, the results were published in a two-part, 505-page article with the assistance of Julia Bell.[89]

Pearson and his biometricians continued to use these craniometric tools in the Biometric Laboratory up until his retirement in 1933. In his last paper on craniometry, which was given at a lecture before the Oxford University Anthropological Society on 25 May 1933 (just before he retired), he expressed concern for the "unsatisfactory nature of the 'standard' planes of the skull".[90] He wanted to illustrate what could be achieved by the use of a cranial coordinatograph and the application of analytical solid geometry to craniometry.[91] By using a cranial coordinatograph, he showed it was possible to obtain a measure of the co-ordinates of any point on the skull referred to by three rectangular planes of reference. An equation was then obtained by using analytical solid geometry for any line on the skull. He considered this to be a most promising field for the craniometricians who would apply Cartesian geometry to the skull.[92]

Silhouettes

The biometricians also used silhouettes for their craniometric work. The first paper published in *Biometrika* on type silhouettes came from the work of Pearson, Ida McLean and Geoffrey Morant in 1928.[93] A year later, Miriam L. Tildesley, who did some of the most extensive work on silhouettes in the Biometric Laboratory, began to collect some measurements from the Albanians.[94] As the Albanians were divided into two groups, Gegë in the North and Toskë in the South, Tildesley wanted to know, "as a physical anthropologist", if the "difference of name cover[ed] also a difference of type".[95] Her silhouettes were constructed mainly from 67 photographs from each group.

The first step was to trace from the photographs with extreme care the outline of the head, introducing the "marked positions of the sub-orbital point and tragion. These drawings were then enlarged by two stages to exactly four times their linear dimension by aid of a Coradi precision pantograph". [96] The process involved enlarging the profile of photographs by the aid of a Coradi pantograph, which was done in two stages to reduce error of judgement. Then, by the aid of a somewhat elaborate co-ordinate system, a large number of measurements were taken on the profile outline. This process was repeated on every individual photograph, and the results were then pooled to obtain a composite; the average of each of the co-ordinates was found and then plotted to give the average type or contour. Figures 3 and 4 represent Tildesley's contour types, derived from the co-ordinate system, of the

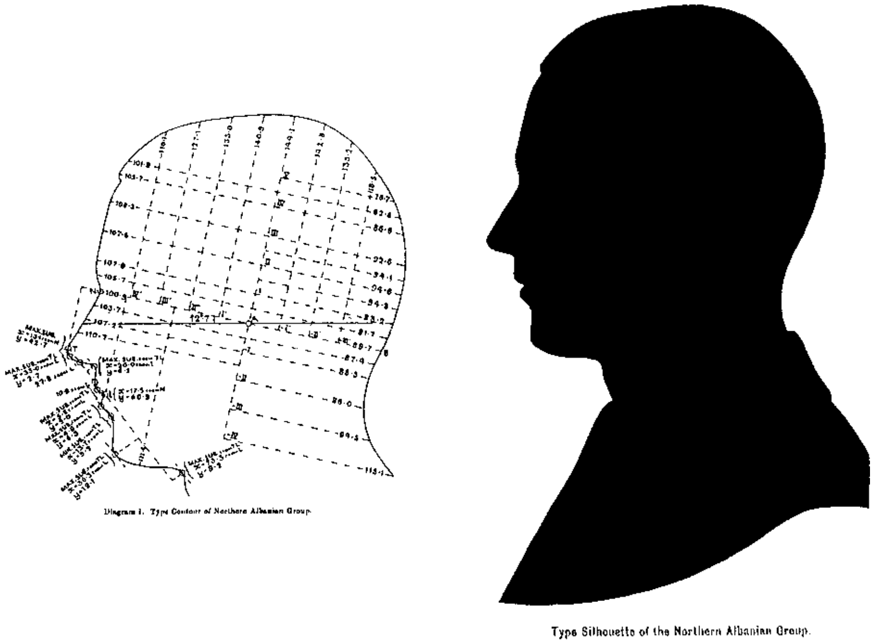

Fig. 3. Tildesley's contour type of the Northern Albanian group.

Northern Albanian and Southern Albanian groups respectively.

She thought that the advantage of using silhouettes from photographs arose from the

> rapidity with which a hundred *standardised* photographs could be obtained in the field as compared with 30 or 40 measurements on 100 men [; this was] a great advantage, and it [left] the laborious task of measurement to be undertaken in the laboratory with proper instruments under standardised conditions.[97]

The biometricians who examined Tildesley's work concluded that there were at least two differentiated groups in Albania, those from the extreme North and the extreme South. It was thought that the comparative value of silhouettes of racial types would be settled only when many others were constructed. Both groups had from the

> European standpoint small [heads], and in the case of the Southern group extremely small heads. [Though] it is possible for two differentiated groups to have faces closely alike ... we must accept the fact that a strong facial resemblance by no means connotes racial identity. Thus physiognomic characters do not necessarily provide the best method of discriminating races.[98]

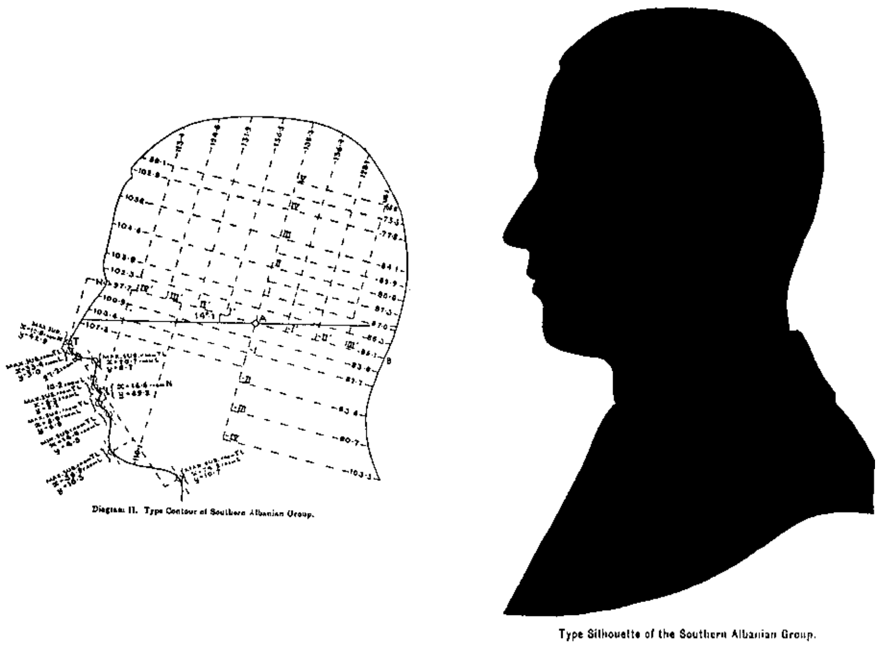

Fig. 4. Tildesley's contour type of the Southern Albanian group.

The Organs of the Biometric Laboratory

Following some of the opposition Pearson met from William Bateson when he read his paper on homotyposis to the Royal Society in November 1900, Weldon suggested that they should set up their own journal.[99] Pearson was grateful for Weldon's suggestion and proposed to him that "the science in the future should be called biometry and its official organ would be *Biometrika*".[100] This journal became the most international of all of Pearson's journals; it was the only one that did not undergo a change of title and still retains its name today. Prior to 1900, Pearson had published his most original and seminal statistical work in *Philosophical transactions*. *Biometrika* was to be in the Pearson family for more than 80 years: Pearson was co-editor with Weldon from 1901 to 1906 (and Galton acted in consultation until 1911), Pearson was principal editor from 1906 to 1933 and co-editor with his son Egon until 1936. Following his father's death in 1936, Egon was principal editor until 1982.

In 1903, Pearson established the *Drapers' Company research memoirs: Biometric series* and in 1904 the *Drapers' Company research memoirs: Technical series*, both of which, funded by the Worshipful Company of Drapers, were to publish the more technical and purely mathematical work going on in the Department of Mechanics and Applied Mathematics. Both of these journals have been almost completely overlooked by historians of science, presumably because they did not fit the preconception that Pearson's work was completely influenced by his interests in eugenics. Moreover, these journals were still very much a part of his Cambridge Wrangler training, and such research and practices could have gone on in Alexander Kennedy's engineering laboratory at UCL.[101] The *Biometric series* published articles that were of a more theoretical nature than articles in *Biometrika*, and the *Technical series* was set up for articles dealing with such problems as elasticity (which was Pearson's speciality in mathematics in the late 1870s and early 1880s). Such articles included, for example, studies of stresses in masonry dams and flexure in prisms. All of the journals mentioned thus far show that Pearson was clearly a pluralist whose work cannot be reduced to one entity.

The early issues of *Biometrika* dealt with the quantification of natural history, demonstrating empirical evidence of natural selection in a variety of plants and animals plus extending Pearson's work on homotyposis. From 1901 to 1906 Weldon edited the papers on natural selection and he also provided assistance to his students at Oxford who were writing articles on natural selection. By 1907, articles on craniometry and physical anthropology began to appear regularly. Interspersed among the articles were papers on further theoretical development of mathematical statistics. Unlike the articles from those working in the Eugenics Laboratory, nearly all biometric articles demanded a fairly high and specialized level of mathematical statistics. As principal author, Pearson wrote 219 articles for *Biometrika* and 10 for the *Drapers' biometric series*. The 229 articles he wrote for these two journals alone represented 35% of his total number of (648) publications. From this total number, Pearson produced 406 (or 63%) statistical papers, notes and books: by contrast, not even 1% of his published papers refer to eugenics.

By 1906 the Biometric Laboratory was becoming very well established, and by then Pearson had developed the foundations for the modern theory of mathematical statistics. Whilst Pearson was managing the Biometric Laboratory, he was also publishing his own statistical papers continually and editing all of his journals. The biometricians were involved in the computation and calculation of various tables of mathematical statistics. Additionally, they had undertaken a number of investigations in the plant and animal kingdom and had pursued crainiometric and osteometric work. Though many of the biometricians co-authored papers with Pearson, a number of them wrote up their own papers for publication.

Pearson also continued to run the Department of Applied Mathematics and was responsible for managing the higher teaching in mathematical physics (which was largely made possible owing to the provisions of his first-class assistant lecturer, Ebenezer Cunningham). Pearson was also helping out students with research work on graphics for the Engineering Degree of the University as well as giving lectures in astronomy and running the students' observatories. He had by then been doing the work of at least three different people aided largely by various teaching assistants, an assistant professor, human computers, calculators and computators in addition to numerous voluntary workers and visiting scholars. In this respect it does not seem surprising that Pearson expressed great hesitation in taking on the directorship of *another* laboratory when Galton approached him in November 1906. Pearson's reluctance makes it less obvious and more problematic to explain that there should have been a connection between the Biometric and Eugenics laboratories.

(*Part 2 of this article will appear in our next issue.*)

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1. Karl Pearson, Letter to Francis Galton, 25 October 1906, in Karl Pearson, *The life, letters and labours of Francis Galton*, iiia (Cambridge, 1930), 298.
2. Karl Pearson, "Report to the Court of the Worshipful Drapers on the present position and past history of the laboratories to which their annual grant has been made", March 1918 (Papers and correspondence of Karl Pearson, University College London (hereafter: KP:UCL), 233), 3.
3. Pearson was Third Wrangler in the Mathematical Tripos at Cambridge in 1879. He studied law and philosophy in Germany, read law at the Inner Temple and was called to the Bar in 1881. He was a polymath whose interests ranged from astronomy, mechanics, meteorology and physics to the biological sciences (including anthropology, eugenics, evolutionary biology, heredity and medicine). For further biographical material on Pearson see M. Eileen Magnello, "Karl Pearson", in Peter Armitage and Theodore Colton (eds), *Encyclopedia of biostatistics* (New York, 1998), 3308–14.
4. Bernard Norton, "Biology and philosophy: The methodological foundation of biometry", *Journal of the history of biology*, viii (1975), 85–93, p. 92.
5. Donald Mackenzie, *Statistics in Britain 1856–1930: The social construction of scientific knowledge* (Edinburgh, 1981), 180.
6. Lyndsay Farrall, "The origins and growth of the English eugenics movement, 1865–1926", Ph.D. thesis, Indiana University, 1970, 101.
7. My own academic background includes formal grounding in statistics and my training in the history of science reflects the historiographical concerns of the 1990s; hence, I do not share the reductionistic approach used by Mackenzie in the 1970s for whom fixed social interests were the basis of historical explanation. See M. Eileen Magnello. "Karl Pearson: Evolutionary biology and the emergence of a modern theory of statistics", D.Phil. thesis, Oxford, 1993. My longer term aim is to produce a biography of Pearson where individuals are less than coherent beings and where social and physical spaces, which are contingent and create opportunities to pursue scientific work, matter, but do not strictly determine this work.
8. M. Eileen Magnello, "Karl Pearson's Gresham lectures: W. F. R. Weldon, speciation and the origins of Pearsonian statistics", *The British journal for the history of science*, xxix (1996) 43–63; *idem*, "Karl Pearson's mathematization of inheritance: From Galton's law of ancestral heredity to Mendelian genetics (1895–1909)", *Annals of science*, lv (1998), 35–94; and *idem*, "Karl Pearson, elastician to biometrician: A mathematician changes contexts" (in preparation).
9. Daniel Todes has examined the scientific-managerial style of the physiology laboratory of Ivan Pavlov, set up in 1891 in St Petersburg. He has likened Pavlov's laboratory to a factory and discussed Pavlov's "scientific and managerial visions [which] suffused all aspects of the production process, shaping ... the construction of the laboratory's physical site, the development

of and use of its technologies; the choice, training and deployment of its workforce; and the processing, form and marketing of its final product". See Daniel P. Todes, "Pavlov's physiology factory", *Isis*, lxxxviii (1997), 205–46, p. 207. See also Kim Pelis, "Prophet for profit in French North Africa: Charles Nicolle and the Pasteur Institute of Tunis, 1903–1936", *Bulletin of the history of medicine*, lxxi (1997), 583–622. Pelis looked at the laboratory of Charles Nicolle and, in particular, his bacteriological work on typhus and vaccines at the Pasteur Institute of Tunis. She has shown how Nicolle brought a closer alliance of his laboratory research with industrial and medical interests and attempted to shift a non-profit oriented pastorian bacteriological administration towards more 'modern' profitable allowances.

10. Gerd Gigerenzer, Zeno Swijtink, Theodore Porter, Lorraine Datson, John Beatty and Lorenz Krüger, *The empire of chance* (Cambridge, 1989), 79.
11. Karl Pearson, *Grammar of science* (London, 1892; 2nd edn, London, 1900; 3rd edn, London, 1911).
12. University of London, University College, "Draft report on the Department of Applied Mathematics and Mechanics", 11 September 1911 (KP:UCL, 11/10).
13. Pearson, *op. cit.* (ref. 2).
14. Pearson, *op. cit.* (ref. 2), 17.
15. Pearson, *op. cit.* (ref. 2).
16. C. P. Blacker, *Eugenics: Galton and after* (London, 1952), 105. Blacker was General Secretary of the Eugenics Society from 1931 to 1952 and was Honorary Secretary from 1952 to 1961.
17. Karl Pearson, "Foreword", *Annals of eugenics*, i (1928), 1; see Pearson's Robert Boyle Lecture delivered before the Oxford University Junior Science Club on 17 May 1907: *The scope and importance to the state of science of national eugenics* (London, 1909), 15.
18. Victor Hilts, *Statist and statistician* (New York, 1981; reprint of his Ph.D. thesis, Harvard, 1967), 00506 [*sic*]. I have shown that Pearson's earliest and most seminal statistical innovations arose from matters of animal speciation. See Magnello, *op. cit.* (ref. 8, 1998).
19. Hilts, *op. cit.* (ref. 18), 00585.
20. Farrall, *op. cit.* (ref. 6), 136.
21. *Ibid.*, 111.
22. Pearson, *op. cit.* (ref. 2), 3.
23. Bernard Norton, "Karl Pearson and statistics: The social origin of scientific innovations", *Social studies of science*, viii (1978), 3–34, p. 5.
24. Donald Mackenzie, "Statistical interests and social interests: A case study", *Social studies of science*, viii (1978), 35–83, p. 64.
25. Mackenzie, *op. cit.* (ref. 5), 105.
26. *Ibid.*
27. Daniel Kevles, *In the name of eugenics* (New York, 1985), 39.
28. Theodore Porter, *The rise of statistical thinking* (Princeton, 1986), 305.
29. Rosaleen Love, "Feminism and eugenics: Alice Lee and Ethel Elderton", *Annals of science*, xxxvi (1979), 145–58, p. 147; Judith R. Walkowitz, "Science, feminism and romance: The Men's and Women's Club", *History workshop*, xxi (1986), 37–59, p. 48.
30. Gigerenzer *et al*., *op. cit*. (ref. 10), 148.
31. Richard Soloway, *Demography and degeneration* (Chapel Hill, 1990), 117–18.
32. Farrall, *op. cit.* (ref. 6), 132–41; Mackenzie, *op. cit.* (ref. 5), 107. In 1903 Pearson set up a university bank account for the Drapers' Biometric Laboratory, and in November 1912, "a separate University banking account [was] opened and kept called the University of London, Galton Laboratory Account". See Karl Pearson, "Report of the Galton Laboratory Committee: 4

December 1912" (KP:UCL, 242).

33. Karl Pearson, "Report to the Court of the Worshipful Drapers on the Galton and Biometric Laboratories especially with regard to their expenditures", March 1925 (KP:UCL, 233), 1. Also see Mari E. W. Williams, "Astronomical observatories as practical space: The case of Pulkowa", in Frank A. J. L. James (ed.), *The development of the laboratory: Essays on the place of experiment in industrial civilisation* (London, 1989), 118–36.
34. Karl Pearson, Foreword to the first volume of *Annals of eugenics* (1928).
35. E. H. Pooley, letter to Karl Pearson, 14 December 1904, Archives of the Drapers' Worshipful Company, A2/18.
36. Karl Pearson, "Report on the work done owing to the Grant made by the Worshipful Company of Drapers to the Department of Applied Mathematics, University of London, University College" (1903–9) (KP:UCL, 233), 7.
37. Pearson, *op. cit.* (ref. 1), 258. Galton had requested that it should be titled the Eugenics Record Office.
38. Schuster, who had investigated the variation of snails in Naples, had been recommended by Weldon. W. F. R. Weldon, letter to Karl Pearson, 25 June 1900 (KP:UCL, 891).
39. Pearson, *Life*, iiia (ref. 1), 258.
40. *Ibid.*, 297.
41. *Ibid.*
42. Pearson, *op. cit.* (ref. 2), 3.
43. Pearson, *op. cit.* (ref. 2).
44. For a discussion of the significance of teaching in laboratories see Graeme Gooday, "Precision measurement and the genesis of physics teaching laboratories in Victorian Britain", *The British journal for the history of science*, xxiii (1990), 25–51.
45. Pearson, *op. cit.* (ref. 2). For background information on Ebenezer Cunningham see Andrew Warwick, "Cambridge mathematics and Cavendish physics: Cunningham, Campbell and Einstein's relativity 1905–1911. Part 1: The uses of theory", *Studies in the history and philosophy of science*, xxiii (1992), 625–56. Warwick has argued that Cunningham's work represented a direct contribution to Cambridge electrodynamics rather than to the development of Einstein's relativity theory.
46. Karl Pearson, [Application] "To the Electors to the Chair of Natural Philosophy in the University of Edinburgh, May 28, 1901" (KP:UCL, 11/9).
47. Karl Pearson, [Application] "To the Electors to the Savilian Professorship, Oxford" (10 June 1897) (KP:UCL, 11/9). Yule was a student in Pearson's Engineering course from 1887 to 1890; he then attended Pearson's Gresham lectures from 1890 to 1893 and became a Demonstrator in 1894. He was made Assistant Professor to Pearson in 1896 by the Council of UCL. See Pearson's testimonial in the "Application of G. Udny Yule for post of Principal of West Ham Technical College, January 1898" (KP:UCL, 905).
48. Pearson, *op. cit.* (ref. 46).
49. Karl Pearson, letter to G. Carey Foster, 26 November 1904 (KP:UCL, 233).
50. Karl Pearson, Foreword to *Drapers' Company research memoirs: Biometric series*, i (1904).
51. I am grateful to Andrew Warwick for bringing this to my attention. For an examination of the development of the first mathematical laboratory in Scotland, which E. T. Whittaker founded in 1913 at Edinburgh University, see Andrew Warwick, "The Laboratory of Theory or What's exact about the exact sciences?", in M. Norton Wise (ed.), *The values of precision* (Princeton, 1995), 311–51. UCL was in fact the site of several laboratories including G. Carey Foster's physics lab. in 1866 and Alexander B. W. Kennedy's engineering lab. in 1878. See Gooday, *op. cit.* (ref. 44).

52. Pearson, *op. cit.* (ref. 49).
53. *Ibid.* For an account of the variety and types of microscopes used by biologists, physiologists and non-professional devotees in late-Victorian England, see Graeme Gooday, "Instrumentation and interpretation: Managing and representing the working environments of Victorian experimental science", in B. Lightman (ed.), *Victorian science in context* (Chicago, 1997), 409–37. On the role of microscopes in mid-Victorian England see Graeme Gooday, "'Nature' in the laboratory: Domestication and discipline in Victorian life science", *The British journal for the history of science*, xxiv (1991), 307–41.
54. Alexandra Wright, Alice Lee and Karl Pearson, "A cooperative study of queens, drones and workers in 'Vespa vulgaris'", *Biometrika*, v (1907), 407–22.
55. E. Y. Thomson, Julia Bell and Karl Pearson, "A second cooperative study of Vespa vulgaris: Comparison of queens of a single nest and queens of a general population", *Biometrika*, vii (1909), 48–64. For an analysis of the important role that women played in the culture of Cambridge University physics see Paula Gould, "Women and the culture of university physics in late nineteenth century Cambridge", *The British journal for the history of science*, xxx (1997), 127–49.
56. F. Y. Edgeworth, "Statistical observations on wasps and bees", *Biometrika*, vi (1908–9), 365–86.
57. For an account of the development of mathematical tables for problems relating to mathematical physics, see Warwick, *op. cit.* (ref. 51).
58. In addition to various human calculators and computers, the biometricians who assisted in the planning of these tables for *Biometrika* include the following: W. F. Sheppard (1902), O. H. Latter (1906), R. A. Fisher (1915), Julia Bell, Florence N. David, H. E. Soper, Maxine Merrington, Egon Pearson, William Palin Elderton, R. C. Geary, John Brownlee (1923), L. H. C. Tippett (1925), John Wishart (1927), Egon Pearson with Jerzey Neyman (1931).
59. Karl Pearson (ed.), *Tables of the incomplete Γ-function computed by the staff of the Department of Applied Statistics, University of London, University College* (Cambridge, 1922); *idem*, *Tables of the incomplete beta-functions* (Cambridge, 1934); and *idem*, *Tables of the complete and incomplete elliptic integrals* (Cambridge, 1934).
60. [Karl Pearson *et al.*], "Cooperative investigations on plants. I. On the inheritance of the Shirley poppy", *Biometrika*, ii (1902–3), 56–100. They published their second paper four years later on the "Cooperative investigations on Plants. II. On the inheritance of the Shirley poppy", *Biometrika*, iv (1905–6), 394–426. For a detailed account of the biometricians work on homotyposis for plants see Magnello, *op. cit.* (ref. 8, 1998).
61. Some of the biometricians who worked on this project include the following: Cicely Fawcett, Alice Lee, Agnes Fry, Leslie Bramley Moor and G. Udny Yule. Pearson's wife, Marie, and one of his friends from King's College, Cambridge, Robert Parker, also gave their assistance.
62. Karl Pearson, "Walter Frank Raphael Weldon, 1860–1906", *Biometrika*, v (1906–7), 46.
63. The memoir was presented to the Royal Society on 6 October 1900 and published a year later in Karl Pearson with Alice Lee, Ernest Warren, Cicely D. Fawcett and others: "Mathematical contributions to the Theory of Evolution. IX. On the principle of homotyposis and its relation to heredity, to the variability of the individual, and to that of the Race. Part I, Homotyposis in the Vegetable Kingdom", *Philosophical transactions of the Royal Society*, ser. A, cxcvii (1901), 285–379. This was followed up by Karl Pearson, "Mathematical contributions to the Theory of Evolution: On the homotyposis in homologous but differentiated organs", *Proceedings of the Royal Society*, lxxi (1903), 288–313.
64. W. F. R. Weldon, "A first study of natural selection in *Clausilia laminata (Montagu)*", *Biometrika*, i (1901–2), 110–23. One of Weldon's students followed up this work when he began to look for empirical evidence of natural selection in the spiral of the snails. See A. P. Cesnola,

"Preliminary note on the protective value of colour in *Mantis Religiosa*", *Biometrika*, iii (1904), 28–60, and *idem*, "A first study of natural selection in '*Helix Arbustorum*' (Helicogene)", *Biometrika*, v (1906–7), 387–99.

65. See Peter Bowler, *The eclipse of Darwinism* (Baltimore, 1983), 39 and John Maynard-Smith, *The theory of evolution* (Harmondsworth, 1958), 156.
66. Weldon, *op. cit.* (ref. 64), 122.
67. All of these methods of correlation have been examined in detail in Magnello, *op. cit.* (ref. 8, 1998).
68. Pearson, *op. cit.* (ref. 2), and *op. cit.* (ref. 34).
69. Pearson, *op. cit.* (ref. 34), "History of the Biometric and Galton Laboratories", Appendix 1. See also Pearson, *op. cit.* (ref. 13), 1.
70. Pearson, *op. cit.* (ref. 34).
71. Pearson discusses the integrators, analysers and curve plotters in Pearson, *op. cit.* (ref. 34), 3. The other instruments appear in various articles in *Biometrika* from 1907 to 1936.
72. Geoffrey Morant and Otto Samson used their distributions from measurements of stature and fitted this to the normal curve by using the χ^2 goodness of fit test. See Morant and Samson, "An examination of investigations by Dr. Maurice Fishberg and Prof. Frank Boas dealing with measurements of Jews in New York", *Biometrika*, xxviii (1936), 1–31, p. 9.
73. See, for example, William Palin Elderton, "Adjustments to the moments of J-shaped curves". *Biometrika*, xxv (1933), 179–80; *idem*, "Tables for testing the goodness of fit of theory to observation", *Biometrika*, i (1901–2), 155–63; R. C. Geary, "A special expression of the moments of certain symmetrical functions", *Biometrika*, xxv (1933), 184–6; V. Romanovsky, "Note on the method-of-moments", *Biometrika*, xxviii (1936), 188–90; M. R. E. Shanawany, "An illustration of the accuracy of the chi-square approximation", *Biometrika*, xxviii (1936), 179–81.
74. O. L. Davies, "On asymptotic formulae for the hypergeometric series", *Biometrika*, xxvi (1934), 59–107; G. H. Hansmann, "On certain non-normal symmetrical frequency distributions", *Biometrika*, xxvi (1934), 129–95; E. J. Martin, "On corrections for the moment coefficients of frequency distributions when the start of the frequency is one of the characteristics to be measured", *Biometrika*, xxvi (1934), 12–58.
75. Pearson set out his scheme of measurement for discrete variables including the sub-classifications of nominal, ordinal and dichotomous variables in his paper with Alice Lee on the "Mathematical contribution to the theory of evolution. VIII. On the inheritance of characters not capable of exact quantitative measurement. Part I. Introductory. Part II. On the inheritance of coat-colour in horses. Part III. On the inheritance of eye-colour in man", *Philosophical transactions of the Royal Society*, ser. A, cxcv (1900), 79–150.
76. Some of the other methods of correlation include Equaprobable tetrachoric correlation, Mean contingency coefficient (φ^2), Mean square contingency coefficient, Marginal centroids, Triserial correlation, Eta (η), Three row η, the correlation of grades, and the polychoric correlation which he devised with his son Egon. See Karl Pearson with Egon Pearson, "On the polychoric coefficients of correlation", *Biometrika*, xiv (1922), 127–56.
77. Pearson first used the C.R.L. in his paper with Adelaide G. Davin, "On the sesamoids of the knee-joint, Part I. Man. Part II. Evolution of the sesamoids", *Biometrika*, xiii (1921), 133–75, 350–400. The C.R.L. was defined in his paper "On the coefficient of racial likeness", *Biometrika*, xviii (1926), 105–17.
78. Karl Pearson, "Mathematical contributions to the theory of evolution. III. Heredity, panmixia and regression", *Philosophical transactions of the Royal Society*, ser. A, clxxxvii (1896), 253–318.
79. Karl Pearson, "Variation in man and woman", *Chances of death* (London, 1897), 256–378, p. 281.

80. Pearson, *op. cit.* (ref. 78), 279.
81. Pearson, *op. cit.* (ref. 78). Like his father and his younger brother, Arthur read law at the Inner Temple and he was called to the bar in 1877. Arthur acquired his double-barrelled surname by Royal Licence in 1885. Thomas Gee, who had no children, was a friend of the family. After his wife died, he gave a portion of the estate to the elder Pearson son, Arthur, on the condition that he would adopt Gee as part of his surname. William Gee, letter to William Pearson (1874) (KP:UCL, 9/3).
82. Karl Pearson and Cicely D. Fawcett, "Mathematical contributions to the theory of evolution: On the inheritance of the cephalic index", *Proceedings of the Royal Society*, lxii (1898), 413–17, p. 413.
83. Karl Pearson with Alice Lee, "Data for the problem of evolution in Man. VI. A first study of the correlation of the human skull", *Philosophical transactions of the Royal Society*, ser. A, cxcvi (1901), 225–64. A second study was completed in the following year, in Karl Pearson and Cicely Fawcett assisted by Alice Lee, "A second study of the variation and correlation of the human skull, with special reference to the Naqada Crania", *Biometrika*, i (1901–2), 408–67.
84. Karl Pearson and Julia Bell, "A study of the long bones of the English Skeleton: Part 1. The femur", *Drapers' Company research memoirs: Biometric series*, x (1919), 1–224, p. 3.
85. Thompson had assisted Weldon some years earlier when he had taken measurements of the frontal breadth of the carapace of the Plymouth shore crab.
86. Pearson, *op. cit.* (ref. 78), 278.
87. Pearson, *op. cit*. (ref. 78).
88. Pearson, *op. cit*. (ref. 78), 271.
89. Karl Pearson and Julia Bell, *op. cit.* (ref. 84); "Part 2. The femur of man with special reference to other primate femora", *Drapers' Company research memoirs: Biometric series*, xi (1919**)**, 226–505.
90. Karl Pearson, "The cranial coordinatograph, the standard planes of the skull, and the value of Cartesian geometry to the craniologist, with some illustrations of the uses of the new method", *Biometrika*, xxv (1933), 217–53, p. 251.
91. Pearson, *op. cit.* (ref. 90), 253.
92. *Ibid*.
93. Karl Pearson with Ida McLean and Geoffrey Morant, "On the importance of the type of silhouettes for racial characterisation of anthropology", *Biometrika*, xxB (1928), 389–400.
94. Miriam L. Tildesley, "The Albanians of the North and South. (1) Introductory accounts of measurements and photographs taken in 1929", *Biometrika*, xxv (1933), 21–29.
95. Tildesley, *op. cit.* (ref. 94), 21.
96. Miriam L. Tildesley, "The Albanians of the North and South. (2) Discussions of Miss Tildesley's measurements by the staff of the Biometric Laboratory", 29–51, p. 47.
97. Tildesley, *op. cit.* (ref. 96), 42.
98. Tildesley, *op. cit.* (ref. 96), 51.
99. W. F. R. Weldon, letter to Karl Pearson, 16 November 1906, (KP:UCL, 891). This debate has been discussed in Magnello, *op. cit.* (ref. 8, 1998).
100. Karl Pearson, letter to W. F. R. Weldon (written sometime after 16 November 1900) (KP:UCL, 266/9).
101. For more background material on Kennedy, see Graeme Gooday, "The morals of energy metering: Constructing and deconstructing the precision of the Victorian electrical engineer's ammeter and voltmeter", in Norton Wise (ed.), *The values of precision* (Princeton, 1995), 239–82. Also see Gooday, *op. cit.* (ref. 44).

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THE SCIENTIFIC REVOLUTION: HAS THERE BEEN A BRITISH VIEW? — A PERSONAL ASSESSMENT

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The topic your Society's anniversary organizers have kindly invited me to help enliven your celebrations with[1] is obviously riddled with opportunities to indulge in such widely current judgements, or prejudices, as are around the world over on national character. For example, just possibly in the inner recesses of your otherwise fully objective and scholarly minds you may have fleetingly entertained the thought that, prior to daring to stand up and address you, I may have availed myself of a drop of Dutch courage. Or just possibly I have, in the inner recesses of my own, otherwise fully objective and scholarly mind, decided in advance what specifically British view has coloured British historians' approaches to what for good reasons I persist in calling the Scientific Revolution, namely, the broadly empiricist, slightly muddling, not too clear-cut, stressing-the-complexity-of-it-all, somewhat neither-here-nor-there approach so often held to characterize the British mode of doing things.

It is certainly true that, just as you do, and really quite as sober as you are, I like to indulge somewhat in such prejudices because, just as you, I do not hold them to be nothing but prejudices. Sometimes judgements about national character hit a mark quite accurately (though it is not always easy to tell what mark exactly) and in any case, the challenge is not to deny one's harbouring whole ranges of such prejudices, but rather to be aware of their limitations, to stand open for possibly numerous individual exceptions, in short, not to turn into mindless stereotypes what may well be useful first aids in exploring not-too-well-known territory. So, let me use that broad notion of the British approach just called up as my preliminary guideline, going on at once to confront it with some empirical material I work from today so as to see whether and, if so, to what extent it actually holds.

My empirical material, then, is all in my book *The Scientific Revolution: A historiographical inquiry*. It came out with the University of Chicago Press in 1994, it costs £21 in a Leeds academic bookshop, and it contains a critical inventory of, and an extended range of comparisons between, some sixty historians' conceptions of that seventeenth-century historical process in course of which, in most people's including my own unrepentant view, recognizably modern science came into the world.[2] Those sixty historians fairly amply discussed in my book have with few exceptions lived and worked in our own century in widely-spread places like Istanbul

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or Jerusalem or Moscow or Rome or Utrecht, but have been most heavily concentrated in prewar France and Germany, in the postwar United States, and in Great Britain. Taking as a criterion of nationality not necessarily place of birth but rather geographic centre of activity, my topic, then, comes down to the following question: Can anything be identified that is both shared by and specific for the approaches to, and/or overall conceptions of, the rise of recognizably modern science entrusted to paper by (in alphabetic order) J. Desmond Bernal, Herbert Butterfield, G. N. Clark, Alistair C. Crombie, Benjamin Farrington, A. C. Graham, A. Rupert and Marie Boas Hall, Geoffrey E. R. Lloyd, Joseph Needham, Simon Schaffer, Charles B. Schmitt, William Whewell, and Frances A. Yates? If at the start you found my topic boring, maybe you have by now begun to think it might still become mildly interesting.

For of course the sheer list of names is very likely to call up an enormous variety of approaches, of viewpoints, of historical sensibilities, of modes of arguing; in short, of being an historian, one way or the other, of the Scientific Revolution. One may even go so far as to question to what extent many of these people have been historians of the Scientific Revolution. Is Schaffer, who jointly with Shapin has instigated a broad movement of denial that one can profitably speak of such an event in the first place? Did Crombie, who argued that what we tend to find most characteristic about the Scientific Revolution was all prefigured, at least in principle, in earlier times? Did Farrington, has Lloyd, who in their pertinent works addressed the Scientific Revolution from the viewpoint of the question of its non-occurrence in the ancient world? Or did Needham, who did the same for China? Or did Graham, the late sinologist, who — on this particular subject — confined himself to criticizing Needham for holding that question to be at all answerable? Or did Yates, whose views on the Scientific Revolution are scattered over mostly isolated pages of two books on mostly other subjects? Or did Whewell, whose conception of the history of science as a concatenation of individual scientific revolutions *ipso facto* blocked any idea of one, unique Scientific Revolution that he was nonetheless leaning towards for other reasons? So why not seek to ease a little a job that is tough in any case, by limiting ourselves for the time being to those four on my list — Bernal, Butterfield, the Halls — who indeed wrote separate treatises actually called “The Scientific Revolution” or some title very close to that? Would such a move not already make for quite sufficient variety from which to start a search for shared features?

Let us see how far we get that way in identifying commonalities. How about my starting point of suspected overdoses of loose empiricism in the sense of much ongoing story-telling, much stress on complexity, many impressionist flashes of insight, all at the cost of clear-cutness, so to say? On the face of it, no characterization could be farther from the reality of Bernal’s *Science in history*, the second volume of which is devoted in good part to the Scientific Revolution. For this volume seems to do nothing but straightforwardly to set forth, and to seek to make factually plausible, one overriding thesis — that “flourishing periods [of science]

... coincide with economic activity and technical advance".[3] By contrast, both Butterfield's *Origins of modern science* and the Halls' successive books on the Scientific Revolution, when long ago I made my first acquaintance with these classics, struck me as rather neatly conforming to my own prejudices on the distinctive British way. In Butterfield's book, for all the many pithy, often enduring formulations strewn over its pages, Pierre Duhem's and Alexandre Koyré's quite clear-cut yet mutually really incompatible theses about the origins of modern science are jointly diluted into a surely engaging story in which the mutual connection of successive chapters — originally lectures, to be sure — is not always striking, to put it mildly. In the Halls' books one overriding story-line — that of the sometimes marred yet in the end inexorable forward march of modern science as the embodiment *par excellence* of rational thought — is the one idea (besides a no less thoroughly diluted version of Koyré's thesis) to lend some measure of unity to the constantly lamented, ungeneralizable complexity of the whole event.

Now these are very ungenerous ways to characterize those seminal books by Butterfield and the Halls, which did so much to bring a larger public to the historical problem of the rise of modern science and (here Butterfield in particular was very compelling) to its world-historical significance. Nor, on further reflection, have I found these early judgements of mine quite deserved. Gradually overcoming at least in part my sense of impatience at what by then I surely felt to be a rather typically British mode of addressing historical issues, I began to discover scattered over their books several big ideas, tacitly employed elements of composition even, which are true gems. For example, I found that both Butterfield and the Halls, without making much of the distinction let alone organizing their respective accounts around it, actually did distinguish between what may suitably be called an inner and an outer Scientific Revolution. Making explicit what is implicitly there, one finds roughly the mathematico-physical succession from Galileo/Kepler/Descartes to Newton subsumed under that inner revolution, with a much looser, far less coherent, more observational and crafts-inspired 'outer revolution' being around for centuries already, before, by the early seventeenth century, catching up with the inner revolution then getting under way. Now these, so I thought and think, are extremely fruitful suggestions for how to make our idea of the Scientific Revolution encompass a good deal more than Koyré so beautifully yet narrowly confined it to, without being compelled to throw up our hands in desperation over the sheer unmanageable complexity of it all.

For there, to interrupt the flow of my argument for a moment, rests the true challenge as I see it. Facing as we do an — in view of so many valuable perspectives upon seventeenth-century science in the broadest sense continuing to be put forward — ever-growing apparent complexity of what we were once wont to call the Scientific Revolution, the temptation to resign is growing in proportion. True, no unitary account, such as up to the 'sixties used to be put productively forward with amazing boldness by, for example, Koyré, Dijksterhuis, or Burtt, is capable any more of encompassing what must be encompassed for an account to be even moderately acceptable by our present-day, exacting, textual and contextualist standards. From that, however, it follows in no way to let go altogether, that is, to dissolve the Scientific Revolution into what has recently, though not admittedly in Britain, been proclaimed to be nothing but "a diverse array of cultural practices".[4] The true challenge as I see it is to gather as many big, empirically fruitful concepts and ideas about the Scientific Revolution as we can think up ourselves and find elsewhere, and then go ahead and produce accounts organized around those ideas and concepts to test how far they get us.

One such big idea is that distinction — I now extend it and make it slightly more concrete — between an inner Scientific Revolution of essentially Greek provenance and mathematical content, and an outer revolution much less coherently composed of elements of typically European, both magic- and craft-tinged activism and Leonardo-like striving for observational accuracy. Again, the core of that big idea can be found in Butterfield's and the Halls' books, but underanalysed as such, left mostly implicit, not turned into an organizing principle. Now this, I think, is truly distinctive about the British approach — this hesitation to cut up a pertinent portion of the past into relatively big analytical chunks and make these inform one's entire account, thus turning a story into an argument. Bernal's book is not really a countercase here; I think, instead, that the very same sense of overwhelmedness by the sheer complexity of the past led him — helped not a little by his sociopolitical views, to be sure — to impose a rigid, dogmatically held range of mostly Stalinist notions upon his factual material without (other than in some far looser and mostly unconnected flashes of brilliant insight) making the ideas and the material interact in any productive way.

In one or another fashion then, one finds this aptness to feel overwhelmed by the complexity of the past in very many otherwise most divergent views on the Scientific Revolution emanating from these isles. "Where is the thesis?", the late Richard S. Westfall (as I have reliably been told) used to ask. I have so very high a regard for Westfall as an historian because it was in every case crystal clear what his never simple-minded thesis was, which he went on to organize his empirical material around, to enliven it by, to clarify it with, in precisely that productive intertwinement between thesis and historical facts invoked to underpin and illustrate it by, which I myself tend to admire most in history writing. "Where is the thesis?", I often found myself wondering when historiographically assessing so many in so many senses truly significant, even exciting contributions from literally all those British authors upon my alphabetic list. Where, for instance, is Needham's thesis? Needham was most certainly not a British empiricist in that broad sense I used as my working hypothesis right at the start and have now replaced with an, I hope, more nuanced and also more tenable conception of the British tinge. He was certainly no vague impressionist; he surely knew how to set up a running argument rather than rambling on without a sense of direction, and still, where was his thesis? It took me about half a year to go through the maze of his truly fascinating and enjoyable work and count in the end six such theses, of which he never bothered to put down how they might be thought to hang together, let alone how they were related to two other theses one can see him to have avoided at almost any cost while really, albeit almost in secret, endorsing them in the fine print of his work. Or take the case of almost every other Britain-born study addressing major questions of the how and why of the Scientific Revolution. However valuable the gems of insight frequently to be culled from them — and this is not an empty compliment but the experience of years of historiographical study — I had to fetch them up from deep down, rather than finding them readily expressed as such at the surface, like with Burtt or Duhem or Dijksterhuis or Koyré or Kuhn or Ornstein or Sambursky or Westfall (to stick to alphabetic listing). Now why is that so? Quite possibly, through my own failing — I may well be too dense or too lazy to grasp all but the obvious. For the time being, at least, you may allow me to seek for an answer in another direction, fittingly to be given shape as a historical, or rather, a historiographical thesis.

My thesis comes down to this. British historians of the Scientific Revolution tend to feel so overwhelmed by the complexity and manifoldness of their empirical material as to shun away from setting up a clear-cut thesis about it fit to engage in productive interaction with it. "Tend to", I said, for I am not going to maintain that there are no exceptions to this rule either way — of more than one non-British historian the same can surely be said, and I can equally think of British historians of science whose work is mostly or even wholly exempt from such a sense of undue overwhelmedness. This particular sense of overwhelmedness, then, seems to me to be the crux of the matter. In one sense, to be sure, every historian worth his salt shares it — the past is so complex and manifold as to make us rightly view with intense distrust anyone addressing the past who appears never in his or her scholarly life to have felt that way. That, at bottom, is where our misgivings come from when we see members of more generalizing disciplines come along to squeeze the past into preset, often monolithic patterns, as we tend to assume *a priori* they set out to do. I share those misgivings; I am acquainted with that sense of sheer overwhelmedness, but I also think there are ways to overcome it; ways, that is, to be clear-cut without becoming monolithic. And one corollary of my thesis is that British historians of the Scientific Revolution have not been too adept overall at recognizing such ways when they see them. Not only do they have that remarkable aptness to qualify their own best theses to death almost as soon as they have thought of one; not only do they (as I illustrated with that idea of an inner and an outer Scientific Revolution) tuck such a marvellous notion away so deeply as hardly to recognise it themselves; they have a somewhat odd relationship with theses of others as well. Take, by way of one example, the 1974 collection of essays from *Past and present* ostensibly dealing with the Merton thesis. One feature I still very vividly recall from working my way through that collection was the inability of most participants to address the Merton thesis, if by that notion we understand a thesis recognisably there in Merton's own book on *Science, technology and society in seventeenth-century England*. I am not saying that Merton made it particularly easy for the reader to distil out of his text what thesis, precisely, he was defending; but I am saying that quite frequently, and particularly in these isles, it was turned into a caricature, out of (and this is my point here) a general sense of unease with historical theses as such. If at all recognised, in one's own work or that of others, such theses tend to be underplayed, and/or viewed in isolation from one another, and/or blown up out of all proportion to their possible explanatory range, subsequently to be cut to pieces for that very reason rather than cut down to proper size in productive interaction with what other, similarly limited historical theses may have taught us.

It is my impression that this not uniquely yet altogether rather peculiarly British unease with historical theses has contributed its bit to the present quandary in which, historiographically speaking, the so-called so-called Scientific Revolution finds itself. Plenty of marvelously perceptive and productive ideas are around by now, calling, I would say, for a measure of careful integration — instead, the impossibility of rendering any reasonably coherent account of how modern science came into the world is by now being turned into almost an article of belief. To be sure, a good portion of what, in this connection, an American correspondent of mine recently called "forlorn postmodern angst" has quite something to do with that belief as well, yet I also think that that angst has found inordinately much food in these isles to feed on.

What is the right level upon which to generalize about the past?, is the root question here. I am not saying that I know the full answer; I am not even saying that there is only one answer, as there are no doubt several such levels, some of which have been explored by certain historical sociologists, others by historically minded philosophers, and again others by historians of science pure and simple. Such explorations, it is my impression, have too rarely come from the United Kingdom which, in this sense of an unduly enduring overwhelmedness with the manifoldness of the past, has failed to put the final touches to those numerous, Britain-cut gems of insight into the broad process of the Scientific Revolution. No distinctive British view of the Scientific Revolution, to be sure, as contributions have been as diverse *qua* content as may be expected from such a pluralism-loving nation; but, indeed, a distinctively British approach to it. I suppose that, if I am called to defend this thesis of mine against your objections on the floor or later in the corridors, a drop of Dutch courage might well come in handy.

REFERENCES

1. This piece was originally a lecture for the British Society for the History of Science 50th Anniversary Conference, held in Leeds from 9 to 11 September 1997. As such it was part of a session expressly set up to give the floor to five scholars from abroad invited to look back and consider what, if anything, has been distinctive in British historiography of science, whether positively or negatively so. Apart from some slight formalization here and there, I have left the occasional character of the piece intact.
2. The admirable phrase "recognizably modern science" occurs with some frequency in Stillman Drake's numerous writings on Galileo.
3. J. D. Bernal, *Science in history* (London, 1969; first publ. 1954), 47.
4. S. Shapin, *The Scientific Revolution* (Chicago, 1996), 3.

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BOOK REVIEWS

Discoveries Ranked

Medicine's Ten Greatest Discoveries. Meyer Friedman and Gerald W. Friedland (Yale University Press, New Haven, 1998). Pp. 320. £19.95.

For some thirty years it has been unfashionable to write narrative history about "great discoveries" in medicine, to call them "great" or to link them to individual "great men" and label these men as the "discoverers". Those who still do this are nearly always elderly medical men glorying in their own professional past. Professional historians no longer write in this way. The authors of this book are both elderly physicians who, they tell us, "have spent decades ourselves in making medical discoveries". This gives us the context.

What is a medical 'discovery'? We are left to work this out. From the chapter headings and the text, it seems that a 'discovery' is an addition to medical knowledge that is still believed to be true. Each discovery is named with that of the person who, the authors thought, began the process. To their credit they go on to discuss later developments and the people involved but the arrangement is misleading. For example, Pasteur and Koch do not appear in any chapter heading yet both are hidden under "Antony Leeuwenhoek and bacteria". Alexis Carrel occupies nearly as much space as the titular Harrison in "Ross Harrison and tissue culture". It is all rather confusing.

The authors support the casual, rather than the causal, view of history. They make no attempt to put the 'discoveries' into context or even to discuss such mysteries as why, after Davy suggested that nitrous oxide might be used to ease the pain of surgical operations, it was half a century before this was tried. They emphasize at some length the small occurrences and coincidences that led to the discoveries — Leeuwenhoek leaving his rainwater in an open container, Crawford Long attending an "ether party", Roentgen glancing at "a tiny scrap of material lying, solely by chance, near his Crookes tube". They are keen on a hierarchy of importance among the discoveries and conclude, as most people probably would, that Harvey and the circulation of the blood is top of the class. They are also keen to emphasize their belief that the 'discoverers' were not geniuses but inquisitive people with "patience, focus, and organization" and with "total understandable mental capacity".

Undoubtedly most of the discoveries described here have been of great importance to Western medicine but why is insulin omitted? It has proved to be one of the great 'advances' of medicine. Conversely, the importance of cholesterol is still disputed, yet the authors insist that it is one of the ten most important discoveries in modern medicine. The “seemingly gentle hen”, they say, is and has been the “most murderous animal for millennia” who spreads “the deadliness of cholesterol” through her eggs. Such language suggests a strong personal agenda.

Will these discoveries continue to be regarded as the “greatest” discoveries of Western medicine? One can only guess. But let us remember that sliding internal organs and “focal sepsis” were once believed to be “great discoveries” and that Egas Moniz won the Nobel Prize for his pioneering work on prefrontal leucotomy (lobotomy).

In spite of these drawbacks, the book is readable. Drawn mostly from secondary sources and laced with important primary sources, it conveys the excitement of modern medicine and makes much of it comprehensible. It is the sort of book that could well inspire a young person to choose medicine as a career. Since such books are now seldom published, this alone would justify its publication.

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Women and Science

“Women, Gender and Science: New Directions”, *Osiris,* vol. xii (1997). Ed. by Sally Gregory Kohlstedt and Helen E. Longino. Pp. 222. $39 (hardcover), $25 (paperback).

For some decades now, scientific knowledge and practices have been a major focus of feminist scholarship. This volume, which had as its origin a workshop at the University of Minnesota, seeks to address “where we are in the mid-1990s”: eleven articles by historians and philosophers of science and technology give an overview of the contribution of feminist scholars to the historical and philosophical understanding of the sciences and of the new questions that have emerged. Stressing the fruitfulness of interdisciplinary dialogue, the book brings together scholars who work on gender and science, those who work on women’s participation in the sciences, and those who work on both, covering the period from the seventeenth to the late twentieth century.

In the first chapter, Evelyn Fox Keller explores how research on “women in science” can relate to “gender and science” in an analysis of the life of the developmental biologist Christiane Nüsslein-Volhard — the first and only woman director of a Max Planck Institute for biological research and a recipient of a Nobel Prize in 1995. In another biographical article, Elvira Scheich analyses the experiences in and approaches to scientific practice of two women pioneers in their academic fields, the geneticist Elisabeth Schiedman (1881–1972), who lived most of her life in Berlin, and the physicist Lise Meitner (1878–1968), who, being Jewish, was forced to leave Germany in 1938.

A number of articles focus on the nineteenth century. Ann Shteir presents her work on women, gender and the history of botany. She shows that during the later eighteenth century, plant study came to be associated with women, but that the process of transforming popular plant study into "botanical science" during the decades between 1830 and 1860 included "defeminizing" it. Also focusing on the history of the gendering of scientific practice, Robert Nye argues that aspects of medicine and science were governed by masculine honour codes, which had been transmitted from early modern times to modern bourgeois culture. These honour codes, which served as part of the "fabric of male sociability among doctors, scientists and other professionals throughout modern Europe", played a role in establishing and maintaining gendered boundaries even after women were formally admitted to medical and scientific training. In another article Nina Lerman examines the persisting gendered assumptions about training for boys and girls in institutions providing technical education to children in the city of Philadelphia from the 1820s to the 1880s.

Two essays deal with the construction and categorization of gender difference in science and medicine. Looking at the gender politics of medical indexing in America from 1880 to 1932, Diane Long argues that the changing vocabulary of women's bodies and health in the *Index catalogue of the library of the Surgeon General's Office* constituted an "unnoticed discourse that reinforced the sexism of professional American medicine". Estelle Cohen, exploring discussions of sexual equality and difference in the medical literature in the period from 1660 to 1760, emphasises that there was a "multiplicity of discourses about women's minds and bodies". Medical opinions could indeed be used to reinforce gender inequality, but, as the author points out, a number of commentators rejected the view that female biology provided the basis for women's subordination. Medical knowledge hence could be used as likely— by women and men — to "collapse traditional social and cultural hierarchies that privileged men".

In another article, Alison Wylie looks at the feminist initiatives that have emerged in archaeology since the late 1980s and considers their implications for feminist science studies. Margaret Rossiter in "Which science? Which women?" makes a case for breaking down research into women in science more into subspecialities, arguing that this will lead to a fuller integration of women into mainstream history of science and a richer and more comprehensive history of science. Turning to contemporary science, Londa Schiebinger declares that the tools of gender analysis, along with others, should be incorporated into an activist agenda to "aid in crafting sustainable sciences" and Sandra Harding restates and reworks her work on women's standpoints on nature.

Although the common theme of women, gender, and science proves to be too broad to give this volume much coherence, the interdisciplinary approach makes it rich in perspectives and subject matter. And the lack of cohesion is certainly a welcome reminder of how wide-ranging feminist scholarship in this area has become.

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NOTICES OF BOOKS

Henry More and the Scientific Revolution. A. Rupert Hall (Cambridge University Press, Cambridge, 1996). Pp. xii + 304. £40.

Henry More was a metaphysical theologian and experimenter whose ideas on space and time influenced Newton. This volume, the first book-length biography of More, focuses primarily on his science and philosophy of nature. It also touches upon More's interests in spiritualism and witchcraft. The first of the book's two sections details More's life and his ideas as a Cambridge Platonist. Its second section examines his ambiguous place in the Scientific Revolution, with individual chapters on his intellectual relations with Descartes, the Royal Society, and Newton.

The Measurement of Starlight: Two Centuries of Astronomical Photometry. J. B. Hearnshaw (Cambridge University Press, Cambridge, 1996). Pp. xii + 511. £65.

Hearnshaw provides an overview of astronomical photometry from Herschel's work in the 1780s to the invention of photometry with the charge-coupled device (CCD) in 1970. Written primarily for practising astronomers, the book is organized around the first three of four technological developments that, the author argues, each 'revolutionized' the field. These technologies are: visual photometry, photographic photometry, and photomultiplier photometry. As such, it will be of interest to historians of technology, including those investigating photography, electronics and computers.

Lise Meitner: A Life in Physics. Ruth Lewin Sime (University of California Press, Berkeley, 1996). Pp. xiv + 526. $30.

The physicist Lise Meitner (1878–1968) was a co-discoverer of nuclear fission. In a career that spanned from the early years of radioactivity to dawn of the 'Nuclear Age', Meitner struggled against the profound bias of her discipline against women and of Germany against Jews. Sime's biography argues that Meitner was less successful in these personal struggles than she was in her professional discoveries: she fled Nazi Germany in 1938 and, relatedly, was effectively erased from her Nobel Prize-winning collaborator Otto Hahn's recounting of his 'creation-of-fission' narrative. Drawing upon scientific publications, archival sources and oral histories, Sime seeks to restore Meitner to her proper place in fission's history as she recounts her extraordinary life.

The Babinski Sign: A Centenary. J. Van Gijn (University of Utrecht, Utrecht, 1996). Pp. vi + 176.

In 1896, Joseph Babinski, a French-trained physician of Polish descent, announced his discovery of the toe reflex that now bears his name. This book studies the history of this reflex. An opening chapter briefly reviews ideas of reflex action from Decartes and is followed by a biographical chapter on Babinski. The chapter on the discovery itself includes a translation of Babinski's text. It is followed by treatments of rival signs, pathophysiology and the 'practicalities' of application, including recommended teaching of administering and interpreting the Babinski sign.

Triumph of Discovery: A Chronicle of Great Adventures in Science. Niles Eldredge, Robert C. Gallo, *et al.* (Helicon, Oxford, 1995). Pp. 254. £20.

This edition commemorates the 150th anniversary of the popular magazine, *Scientific American*. Appropriately, it is itself a popular encyclopaedia of broad scientific subjects (48 of them), written for the volume by leading scientists in each field. Robert Gallo, for example, has written the entry on viruses; Carl Sagan, on solar system exploration. In addition to the expected topics are treatments of addiction, industrial policy, technology and memory. Essays are illustrated and brief — generally 3 to 4 pages. Interspersed throughout the text are chronologies of major developments that defined each decade from the 1840s to the present.

About Time: Einstein's Unfinished Revolution. Paul Davies (Penguin Books, London, 1996). Pp. 316. £8.99 (paperback).

While firmly grounding his study of time in the revolution started by Einstein, Davies does not present a straight-forward history. Instead, he has summarized Einstein's theories and examined their consequences for a select set of temporally-related topics: black holes, time travel, time's arrow, and the 'now', for example. An imaginary interlocutor plays the role of curious non-specialist reader, posing intermittent questions to the author. Davies also discusses the uncharted potential and possible limitations of Einstein's theory of time.

Possessing Nature: Museums, Collecting, and Early Scientific Culture in Early Modern Italy. Paula Findlen (University of California Press, Berkeley, 1996). Pp. xviii + 449. $18.95, £14.95 (paperback).

Findlen's is a tale of two histories: the appearance of museums, and the development of natural history as a discipline, in Early Modern Europe. She locates this tale in the processes of collecting and interrogating nature that went on in Italian museums during the sixteenth and seventeenth centuries. Her analysis spatially locates the museum in a linguistic, philosophical and social matrix; it then examines the museum as laboratory; finally, it looks to the museum as a place where social and scholarly identities were formed. In this way, she argues, the museum informed developments in natural philosophy and the formation of a "scientific culture".

Networks of Innovation: Vaccine Development at Merck, Sharp & Dohme, and Mulford, 1895–1995. Louis Galambos and Jane Eliot Sewell (Cambridge University Press, Cambridge, 1996). Pp. xii + 274. £35/$39.95.

Galambos and Sewell trace the development of private-sector pharmaceutical organizations in the context of medical, scientific and governmental networks. Their inquiry takes them not only through the merging histories of Merck, Mulford and Sharp & Dohme, but also through the four broad cycles of the pharmaceutical production of biologicals — from bacteriology to DNA-based technology. Using archives and oral histories, they examine the relationship between technological innovation and business strategy. Ultimately, the authors are interested in uncovering the ways in which historical study may provide insight into patterns of innovation in contemporary, science-based industry.

Les "Principia" de Newton. Michel Blay (Presses Universitaires de France, Paris, 1995). Pp. 124. FF 45.

This small volume provides a reading of Newton's *Principia*. An introductory chapter reviews ideas about motion that were held when Newton published his treatise. Two subsequent chapters are devoted to the treatise itself, and to Newton's work on projectiles and the mathematics of physics. A final chapter examines the revision and extension of Newton's theories through the application of Leibnitz's calculus.

Stonehenge: Neolithic Man and the Cosmos. John North (Harper-Collins Publishers, London, 1996). Pp. xliv + 609. £25.

North looks to material culture and the history of cosmology in an effort to understand the mind of the people who built Stonehenge. Using a three-dimensional approach, he studies the famous structure both in itself and in the context of similar constructions. Ultimately, he offers what he believes to be the solution to the riddle of Stonehenge. Evidence and conclusions are presented to the general reader (with appendices for the specialist who seeks to confirm them) in a detailed volume that is supplemented by the inclusion of more than 200 figures, 29 photographic plates, glossary and selective bibliography.

The History Today Companion to British History. Edited by Juliet Gardiner and Neil Wenborn, (Collins & Brown, London, 1995) Pp. 840. £25.

Written by six British historians, and supplemented by contributions from numerous specialists, this volume contains over 4500 entries on British history from the Roman invasion to 1979. Entries reflect current historical trends, with attention to economic, social, cultural and women's history. Historians of science and medicine will find topics of interest, including antibiotics, Bedlam, the Black Death, phrenology and vaccination.

A Brief History of Light and Those that Lit the Way. Richard Jerome Weiss (World Scientific Publishing, London, 1995). Pp. x + 185. £13 (paperback).

Weiss's biographically-oriented history of light is intended for the general reader. Its first half moves from the sixteenth to the nineteenth century; its second half is devoted to twentieth-century theories of light. The author periodically interrupts the twentieth-century narrative with chapters he calls "tutorials". These give the reader an introduction to the nature of photons and electrons, with sections on "riding a photon" and "illusion and reality".

Death, Desire and Loss in Western Culture. Jonathan Dollimore (Allen Lane Penguin Press, London, 1998). Pp. xxxii + 384. £25.

The AIDS epidemic has served as a forceful reminder of the long-standing coupling of desire and death. Dollimore examines the tensions of this coupling, not as a pathological, but as a creatively constitutive — and fundamental — dimension of Western thought. It has been central, he argues, to our understanding of individuality, change, gender, and social death. Written for the non-specialist, the volume opens with a study of death and desire in Antiquity and the Renaissance. It then turns to a thematic investigation of its subject in the nineteenth and twentieth centuries, concluding with studies of homosexuality and AIDS. Topics include the philosophy of nothingness in Hegel, Heidegger and Sartre; the "aesthetics of energy" in Nietzsche, Georges Bataille and D. H. Lawrence; and degeneration in Conrad's *Heart of darkness*.

Arrhenius: From Ionic Theory to the Greenhouse Effect. Elisabeth Crawford (Science History Publications (USA), Canton, Mass., 1996). Pp. xiv + 320. $49.95.

Svante Arrhenius (1859–1927) is best known as the chemist who articulated the theory of electrolytic, or ionic, dissociation. Yet, as Crawford underscores in this scientific biography, he also made influential contributions to climatology — particularly concerning the 'greenhouse effect' through study of the influence of carbon dioxide on the temperature of the Earth — and immunochemistry. Indeed, these three subjects, arranged chronologically and framed by a brief biographical sketch and an epilogue, structure the book. In addition to examining her subject's disciplinary boundary-crossing, Crawford also attends to Arrhenius's geographical movements and the effects these changing contexts had on his scientific choices and ideas.

The Gospel of Germs: Men, Women, and the Microbe in American Life. Nancy Tomes (Harvard University Press, Cambridge, Mass. and London, 1998). Pp. xvi + 351. £19.95.

How did the individuals who comprised the turn-of-the-century American melting pot come to have faith in the "Gospel of Germs"? Tomes follows the translation of medical evidence for the existence of invisible, yet fatal, microbes into daily hygienic practices. In so doing, she moves from the laboratory and the public health movement to porcelain toilets and domestic practices, illuminating how a broader public culture of hygiene arose from biological theories of disease. The book attends principally to the period in which germ theory emerged and reigned — 1870–1930 — and concludes with a more condensed consideration of the crisis of faith that has characterized our later, antibiotic-resistant age.

Technological Change. Edited by Robert Fox (Harwood Academic Publishers, Amsterdam, 1998). Pp. 271. £36.

This edited collection brings together essays on important themes and central methodological debates within contemporary studies of technological change. The first of four sections sets forth many of the discipline's methodological concerns. The essays comprising the three subsequent sections are gathered around distinct historical periods and problematics: medieval technology and social change; technology and new perspectives on the Industrial Revolution; and modern — and postmodern — technology in relation to politics and national cultures. Contributors include Trevor Pinch, Thomas P. Hughes, John Pickstone and Donald MacKenzie.

Yerkes Observatory 1892–1950: The Birth, Near Death, and Resurrection of a Scientific Research Institution. Donald E. Osterbrock (Chicago University Press, Chicago and London, 1997). Pp. x + 384. £31.95.

The Yerkes Observatory, built by the University of Chicago and financed by the robber baron C. T. Yerkes, celebrated its centenary in 1997. Osterbock, an astrophysicist and sometime director of the Lick Observatory, draws upon letters, oral histories, scientific papers and newspapers to chart and assess its changing fortunes under its first three directors. Sketching both the research programs and the institutional politics that characterized the famous observatory, he also attends to broader patterns in science funding and knowledge production in twentieth-century America.

The Shorter Science and Civilisation in China, v. Joseph Needham, abridged by Colin A. Ronan (Cambridge University Press, Cambridge, 1996). Pp. xvi + 364. £22.95/$34.95 (paperback).

This fifth volume of Ronan's abridgement of Needham's series focuses on engineering in medieval China. Generously illustrated with figures, photographs and tables, it includes chapters on roads, city planning, hydraulic engineering, and the Great Wall. These technologies are presented not only as impressive individual accomplishments, but also as part of a more general social and material culture.

Where Worlds Collide: The Wallace Line. Penny Van Oosterzee (Cornell University Press, Ithaca, N.Y., 1997). Pp. xii + 234. £14.50 (paperback).

Alfred Russel Wallace first articulated his theory that there existed a 25-kilometre-wide biogeographical line separating "marsupials from tigers" (p. 34), "the Oriental from the Australian" (p. xiii), in 1859. Here was the place, Wallace argued (and Oosterzee summarizes, perhaps with the help of lyrics from the Australian band INXS), where once separate worlds collided. Using a popular, sometimes even fictionalized, narrative style, Oosterzee refashions Wallace's own account of his work in *The Malay Archipelago* by adding general historical background about nineteenth-century evolutionary theories as well as present-day scientific evidence about continental drift and species variation.

The End of Knowing: A New Developmental Way of Learning. Fred Newman and Lois Holzman (Routledge, London and New York, 1997). Pp. xii + 185. £14.99 (paperback).

Science has been *too* successful, revealing a meaningless universe; postmodernism, far from being its nemesis, is its child — and, as such, has not gone far enough to give us an alternative direction for the future. This is the argument of Newman and Holzman. Their book attempts to show a way beyond meaninglessness and modernism. Drawing upon Wittgenstein, Vygotsky and their own experience in creating "anti-institutions", the authors argue that we must reject 'knowing' itself, and instead embrace a more performative approach to the world.

The Comet of 44 B.C. and Caesar's Funeral Games. John T. Ramsey and A. Lewis Light (Scholars Press, Atlanta, l997). Pp. xx + 236. $27.95 (hardcover), $17.95 (paperback).

A classicist and a physicist collaborate to determine when in 44 B.C. Caesar's Comet appeared. They look to independent accounts of the comet's sighting (particularly from China), historical evidence and astronomical analysis, ultimately discerning that it was seen in July, rather than in the more commonly assumed September. Further, as the comet was stated to take place during Caesar's funeral games, the authors not only provide background on the games and the concurrent public festival, but also locate them temporally.

Future Plagues: Biohazard, Disease and Pestilence. Mankind's Battle for Survival. Peter Brookesmith (Blandford, London, 1997). Pp. 176. £16.99.

This coffee-table book provides stories and images of epidemics, past, present and future, for the lay reader. Included are chapters on AIDS, antibiotic-resistant viruses, and biological weapons, as well as summaries on the history of plagues in society and efforts to control or eradicate yellow fever and malaria. All chapters are generously illustrated. The author provides a glossary and list of publications for further reading.

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NOTES ON CONTRIBUTORS

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